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Differences in self-control between ADHD and typical boys as a function of alternative activities.

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DIFFERENCES IN SELF-CONTROL BETWEEN ADHD AND TYPICAL BOYS AS A FUNCTION OF ALTERNATIVE ACTIVITIES

A Dissertation Presented

by

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I dedicate this dissertation to my parents and the memory of my grandparents for their unyielding love, support, encouragement, and faith in me. My parents taught me to appreciate life and have always given me the love and inspiration needed to achieve my goals.

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ABSTRACT

DIFFERENCES IN SELF-CONTROL

BETWEEN ADHD AND TYPICAL BOYS

AS A FUNCTION OF ALTERNATIVE ACTIVITIES

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Differences in self-control between a group of typical and a group of boys clinically diagnosed as having Attention Deficit Hyperactivity Disorder (ADHD) between 5 to 6 years of age were assessed using a procedure in which subjects could select larger, more delayed reinforcers versus smaller, more immediate reinforcers. exchangeable for toys. During two of the six phases of self-control assessments carried out over two days, subjects had access to additionally programmed activities (music and toys). Along with choice data, several collateral measures were collected including different classes of activity (e.g., actometer, out of seat), latency to respond, ratings of enjoyment, verbal and nonverbal time estimations of delay, and contingency descriptions of the self-control task. ADHD subjects chose the delayed, larger reinforcer significantly less frequently over time than did typical subjects, while typical subjects chose increasingly to

self-control over phases. The opportunity to engage in the additionally programmed activities did not alter self-control responding and both groups used the music and toys equally often. Latencies did not differ significantly between the two groups, but were significantly different between phases, with longer latency times during Phase B when the additional sources of reinforcement were available. ADHD subjects became more active over time, although this effect was mitigated during the B Phases. The group members did not differ in their ability to estimate the delays, or in their ratings of task enjoyment, and they could describe the contingencies accurately. The results demonstrated that the choice task proved to serve as an objective way to measure self-control differences between ADHD and other children.

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CHAPTER 1

A REVIEW OF ADHD AND ITS CORE SYMPTOMS

Hyperactivity is a serious disorder that creates problems for the child with hyperactivity, family members, and society. This introductory section suggests ways to apply an operant analysis of self-control to typical and Attention Deficit Hyperactivity Disorder (ADHD or hyperactivity) children. First, studies and interpretations of problems with hyperactive children will be reviewed. Next, studies and models from the operant literature that may have bearing upon the problems of ADHD children and self-control will be presented. A number of operant studies suggest ways to assess and improve self-control behavior; behavior that is often problematic or "lacking" among hyperactive children (Ross & Ross, 1982). By integrating these two areas of research it is hoped that more can be learned about self-control in general, but particularly more about the problems that the ADHD population encounter. Finally, the author suggests ways to apply operant procedures and analyses to assess self-control and learn more about the differences in its expression between typical and hyperactive children.

Hyperactivity

Hyperactivity is considered the most common reason for referrals to child guidance clinics today (Barkley, 1981). Prevalence rates for the disorder in school-age populations vary from 3-5%, with higher rates of occurrence among males and lower socioeconomic groups (Barkley, 1981). Children labeled hyperactive are a heterogeneous group, but researchers agree that they are inattentive, impulsive, and situationally overactive (Campbell & Werry, 1986; Ross & Ross, 1982). Many also have associated deficits, such as learning disabilities, relatively high rates of aggression, peer-related social problems, and emotional problems, including low self-esteem and increased moodiness (Barkley, 1981; Campbell & Werry, 1986). Ross and Ross (1982) succinctly describe hyperactivity as "a high level of activity that is manifested in situations in which it is clearly inappropriate and cannot be readily inhibited upon command" (p. 1).

Although the specific etiology of ADHD is still unknown, there is increasing agreement among researchers that biological factors are responsible for the development of the disorder (Anastopolous & Barkley, 1988; Conners & Wells, 1986). The etiology of ADHD probably varies somewhat from individual to individual, as does the child's responsivity to environmental influences. Most researchers (Anastopoulos & Barkley, 1988; Conners & Wells, 1986; Ross & Ross, 1982) stress an interactional model between environment and physiology wherein a particular infant's biology is differentially affected by environmental factors. A recent review of the ADHD biological research (Anastopoulos & Barkley, 1988) found that there may be several circumstances associated with the disorder, including dysfunction in the mesial frontal and frontal-limbic regions. Perhaps those dysfunctions are related to genetic factors, elevated lead levels, the use of certain anticonvulsant medication, maternal ingestion of nicotine and alcohol during pregnancy, a higher incidence of minor physical anomalies or some combination of these and other multiple biologic and environmental influences.

The following sections will briefly describe the assessment procedures used to identify ADHD, its developmental course and core symptoms, including problems with attention, activity, and noncompliance to rules. A better understanding of hyperactivity and how to treat its associated difficulties, can be accomplished by reviewing its core symptoms.

Assessment of ADHD

Clinicians use a multi-method process to diagnose ADHD but rely primarily on parent interviews and parent and teacher rating scales. Barkley (1988, 1989) suggests that a comprehensive assessment of ADHD also includes an evaluation of the child's social, academic, and family functioning.

Most assessments begin with a structured parent interview in which information is gathered on the developmental course of the child and the presence of DSM

III-R indicators of symptoms, including but not limited to ADHD symptoms. The parents, teachers, and if age permits, child also complete behavior rating scales (e.g., the Child Behavior Checklist, CBCL, Achenbach & Edelbrock, 1983; the Conners Parent and Teacher Rating scales, Goyette, Conners, & Ulrich, 1978). Kendall and Wilcox (1979) have developed a rating scale, the Self-Control Rating Scale (SCRS) specifically designed to measure impulsivity in children. The 33 item test is rated by teachers and some of the questions are only appropriate for children who are old enough to be in structured classroom situations. In fact, normative data are only available for children between the ages of 8 and 11. The scale does offer a way of measuring global self-control problems and may serve as an informative accompaniment to other ADHD measures.

The greatest advantage of the rating scales is that their scores are based on information provided by individuals who have had extensive contact with the child in question. Unfortunately, those raters also may have a biased and unreliable view of the child or the rater may be unfamiliar with normative behavior for a particular age and circumstance.

Direct observational procedures potentially provide some of the most ecologically valid measures of ADHD. A number of systems have been developed, including classroom observation systems (Abikoff, Gittleman-Klein, & Klein, 1977; Campbell, Szumowski, Ewing, Gluck, & Breaux, 1982) and a clinic analogue setting (Barkley, Fischer, Newby, & Breen, 1988). The coding systems measure behavior that is thought to occur at higher rates in ADHD children, including responses such as off-task, vocalizing, out- of-seat, fidgeting, and toy shifts. In the future these systems may reveal some of the contextual and situation specific problems that are so hard to measure in the ADHD population. However, the procedures are often considered too costly and time consuming by some clinicians. The lack of available normative data for the procedures also prevents their adoption on a wide scale basis (Barkley, 1987).

Currently a number of laboratory methods are used to measure symptoms associated with ADHD. The continuous performance test (CPT), one of the most commonly used (i.e., Klee & Garfinkel, 1983), was developed to measure vigilance and sustained attention. It requires a child to search a visual field and locate a specific target or sequence of targets. Scores are based on the number of targets hit, missed, and incorrectly identified, with the number of hits and misses measuring sustained attention and the number of errors reflecting both sustained attention and impulse control (Barkley, 1989). The Gordon Diagnostic System (GDS) is a small, computerized apparatus that administers both a sustained attention (vigilance) and a delay task (Gordon, 1979; McClure & Gordon, 1984). This system is commercially available and presents one of the few standardized, objective systems developed. Normative data for this system are available and the vigilance task may prove to be a useful diagnostic tool in measuring high levels of stimulant responsivity (Gordon, 1985, Barkley, et. al., 1988). The impulsivity (DRL) task on the GDS showed early promise (McClure & Gordon, 1984), but has recently come under question by other researchers who have failed to replicate the developer's findings (Barkley, 1988).

The Matching Familiar Figures Test (MFFT, Kagan, 1966) was one of the first tests used to assess deficits in hyperactive children (see section on Impulsivity later in this Introduction for a more detailed review). In this task children must match a picture from an array to a sample. Latency times and number of errors are recorded and interpreted with available norms. Scores from the task are intended to help identify impulsive and reflective styles of responding, with lower latencies and higher accuracy scores representative of a reflective style of responding. However, the latency score of the MFFT has not adequately identified hyperactive children and its overall ability to discriminate the population from other related clinical groups has been questioned (Douglas, 1988). The test's greatest limitation may be its absence of ecologically valid stimuli. The test is given in a one-to-one situation, a situation in which ADHD children may perform at their best. In this structured testing format few competing reinforcers (e.g., toys in freeplay time) are present to evoke problematic impulsive behavior in ADHD children.

The major advantage of laboratory tests is their objective nature. However, these tests also have their limitations, including a lack of standardization and normative data to interpret their obtained scores. In addition, these instruments typically do not use individually tested-relevant stimuli; most laboratory tasks (e.g., GDS) deliver points to the child for correct responding, with the expectation that the points are "motivaters" or function as reinforcers. Since all individuals have different reinforcement histories, though, it would be unlikely that the responding of every child tested would be reinforced by symbolic stimuli like points. The value and utility of a point system would be increased if the points could be exchanged for child selected items that did demonstrate reinforcing effectiveness (e.g., edibles, baseball cards, money). (See section on Impulsivity for more on the issue of using relevant stimuli.)

<u>Treatment of ADHD</u>

A multimodal treatment approach combining drug and behavioral therapies is often needed to treat the complex symptoms of ADHD. Pharmacologic interventions are the most prevalent treatment procedures used to reduce symptoms associated with ADHD. Psychostimulants and antidepressants are two classes of drugs that have been proven effective in managing the disorder. Although individual children's responses to stimulants seem to be quite variable, a large percentage of them (about 70-90%) show desirable behavioral changes within a short period of time (Conners & Wells, 1986).

Within the past 10 years there has been a proliferation of environmental interventions developed specifically to address the symptomalogy of the ADHD population. Most of the techniques involve training parents and teachers in the use of stimulus control, contingency-management, and self-instructional procedures. The majority of the programs involve token and response cost components accompanied by self-instructional procedures. Of the contingency management programs, those that include a response cost component seem to be the most effective and have demonstrated the best maintenance, after the interventions have been removed (Pfiffner, O'Leary, Rosen, & Sanderson, 1985; Sullivan & O'Leary, 1990).

Developmental Aspects of ADHD

A review of the developmental aspects of ADHD will help one understand how its associated deficits become expressed as the children mature and become more independent and interactive with their supporting environment. Symptoms of hyperactivity are often noticed by parents of these children as early as infancy (Campbell, Breaux, Ewing, Szumowski, 1986; Lambert, 1972; Ross & Ross, 1982). At this age, parents most frequently note the infant's high rates of activity, irritability, and irregularity in feeding, sleeping and eating habits. As hyperactive children develop, the differences between them and their peers becomes more pronounced, particularly as the environmental structure around them becomes more restrictive. While these youngsters are expected to modulate their behavior in response to greater structure, such as nap and story time in preschool, they tend to be unable to do so in comparison to their nonaffected peers. In addition, because their verbal repertoires are developing, parents and others expect the children to comply to verbal instructions. Parents begin to notice extreme problems of noncompliance and their need to constantly repeat commands. Indeed, Barkley (1981, 1988, in-press) considers failures in compliance to rules and commands one of the hallmarks of hyperactivity. Around this time, problems in the social world of the hyperactive also become obvious. As Whalen and Henker (1985) describe it, they tend to engage in behavior that is "inept, irritating, immoderate, aggressive, or intense" (p. 447). Problems in hyperactivity become most prominent when these children are of school-age and are expected to sit at a desk for extended periods of time and engage in teacher-selected activities.

The problems a hyperactive child experiences tend to persist through adolescence and adulthood (Barkley, 1981; Kendall & Braswell, 1985; Ross & Ross, 1982). Approximately one-third to one-half of hyperactive children continue to have problems associated with hyperactivity through adulthood (Weiss & Hechtman, 1986). These problems include the core features of the syndrome, inappropriate activity, impulsivity, and attentional deficits, along with deficits in social interaction skills, negative self-statements, and a history of antisocial behavior (Weiss & Hechtman, 1986). Clearly, hyperactivity can be a life long intrusive and damaging disorder.

Core Symptoms of ADHD

As mentioned above, children who fall under the label of hyperactivity are a heterogeneous group, with behavior patterns varying within the group (Conners & Wells, 1986). The diagnostic criteria in the current classification system of the revision of the third edition of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-III-R: American Psychiatric Association, 1987), was written to reflect the differences within the group. To be diagnosed as ADHD, children must display 8 out of a possible 14 symptoms of the diagnostic criteria (see Appendix A for the criteria). All of these items fall under what are commonly regarded as the core features of ADHD, including the following (Barkley, 1988): "age inappropriate levels of inattention, impulsivity, and overactivity;" and "the inability of the children to restrict their behavior to situational demands (self-regulation), relative to same-age normal children" (p. 70). Definitional problems exist, however, with the first three descriptors because they are vague and cannot explain the situational differences often found in the behavior of the ADHD (see e.g., Roth & Schroeder, 1976; Zentall, 1984).

Inattention

Of the three symptoms, inattention may be the most vague. Much of the research on attention in hyperactivity has been concerned with sustained attention (e.g., uninterrupted time engaged in a task). Douglas and her colleagues have proposed (Douglas, 1972; Douglas & Peters, 1979; Firestone & Douglas, 1975) that the major deficit in hyperactivity is an inability to sustain attention and inhibit responding in situations requiring, "focused, reflective, organized, and self-directed effort." (1979, p. 173). A typical investigation of sustained attention involves measuring and comparing reaction times of hyperactive to normal children on concept learning tasks (Friebergs & Douglas, 1969; Parry & Douglas, 1983).

These procedures require subjects to identify exemplars of a concept when stimuli are presented under varying reinforcement schedules. Attention also is studied in delayed reaction time tasks, where response times to a reaction signal are compared between groups and reinforcement conditions (Firestone & Douglas, 1975). These studies have shown slower reaction times with more variability and errors for hyperactive children under "partial" (FR2) reinforcement schedules. However, under continuous reinforcement schedules (FR1), differences between the groups disappear. Firestone and Douglas (1975) have concluded that hyperactive children have slower and more variable reaction times because they are incapable of sustaining attention to the task at-hand.

However, if sustained attention were a primary deficit then it should be exhibited under all circumstances, and clearly that is not the case with this population. In fact, Douglas and her colleagues have shown in these studies on attention (Firestone & Douglas, 1975; Friebergs & Douglas, 1969; Parry & Douglas, 1983) that those with ADHD can maintain sustained attention under some circumstances (i.e., continuous reinforcement). Evidence from other researchers indicates that the behavior of the hyperactive person changes depending on the rate of reinforcement available in a situation. For example, studies have shown that rates of activity and on-task behavior in the hyperactive vary depending upon the activity (Porrino, Rapoport, Behar, Sceery, Ismond, & Bunney, 1983), the instructional restrictiveness of a situation (Routh & Schroeder, 1976), and the rate of reinforcement delivered (Barkley, Copeland, & Sivage, 1980). Barkley (1989) hypothesizes that attention deficits are most likely seen during dull and repetitive tasks. Some researchers have not taken the situational variability of the disorder into account and have simply assumed that there is an overall "attentional" deficit in these children. This demonstrates the danger of using a construct such as "attention" in any situation; the term assumes that there is something amiss inside the individual and does not specify a functional relation between the problem and the environment.

It is clear, however, that the popularity of invoking cognitive constructs has had an enormous effect upon the conceptualization and research in this field. Evidence of this can be found in the current and prior Diagnostic and Statistical Manual, where the words "attention-deficit" appear in the label for hyperactivity. Describing the behavior of the hyperactive as attention-deficient is troubling because the construct assumes an explanatory role, which in turn discourages further inquiry into the relations between various stimuli and hyperactive behavior. If much is to come from the study of attention within the hyperactive population, experimenters will need to operationalize the term "attention" better, as well as systematically evaluate the conditions under which the behavior changes. When researchers do that, it may no longer be necessary to conceptualize the operationalized behaviors as attention, but simply as sets of behaviors subsumed under a particular response class, that change in predictable fashion under particular environmental conditions. [See Barkley (in press), for a more thorough discussion on the role of attentional models in hyperactivity.]

<u>Rate and Appropriateness of Activity</u>

Overactivity is perhaps the oldest and most commonly used adjective used to describe the hyperactive. Abundant evidence suggests that in numerous contexts hyperactive children are more active than control children (Porrino et al., 1983; Prior, Wallace, & Milton, 1983; Zentall, 1984; Zentall & Meyer, 1987). However, at this point, most researchers are concerned with the <u>inappropriateness</u> of activity in the ADHD, rather than the <u>rate</u> of activity (Ross & Ross, 1982). Researchers are becoming more interested in how specific contexts affect rate of activity, and in what manner it exaggerates the differences in rates between the hyperactive and the nonhyperactive. Draeger, Prior, and Sanson (1986) demonstrated that hyperactive subjects were more active than controls when an experimenter was absent from a laboratory setting than when she was present. The experimenter may have functioned as a discriminative stimulus for generalized compliance. The experimenter's presence decreased excessive behavior by "unintentionally" providing supplemental contingencies external to the task.

Additional research on contexts and activity (Zentall, 1984), showed that hyperactive subjects were more active (e.g., moving up and down, fiddling with things, talking) during homework and play times, than during meals and television time. This research was based on parent and teacher rating scales, while a similar study (Porrino et al., 1983) used actometers (mechanical recording devices) in conjunction with parent diaries. The results showed that hyperactive boys exhibited higher rates of activity, regardless of the time of day, or day of the week. There were differences in the rates of activity and the magnitude of differences between groups, depending upon the situation. Both groups exhibited low levels of activity during television watching and higher rates during unstructured free time, such as outside play and recess. In this study, however, the largest differences between the hyperactive and control children, were seen during structured times, including reading and mathematics periods.

Two additional studies (Gordon, 1979; McClure & Gordon, 1984) conducted in a laboratory setting, assessed differences in the rates of responding of hyperactive against controls subjects. Both studies compared subjects' responding on a Differential Reinforcement of Low Rate (DRL) 6 second task. The first study compared hyperactive to nonhyperactive children (Gordon, 1979), and the second study compared emotionally disturbed hyperactive children to emotionally disturbed children (McClure & Gordon, 1984). Both studies showed higher rates of nonreinforced responding from the hyperactive subjects over their control groups. Interestingly, Gordon (1979) also found that hyperactive subjects tended to engage in more overt physical behaviors during the task, while controls engaged in fewer overt ones, but reported the use of covert behaviors more frequently. These studies can also be interpreted as experiments on impulsivity, since the DRL task requires inhibition of responding.

Perhaps hyperactive children are more active, but it may only be obvious under circumstances in which the higher rates of activity cause problems, as when the child chooses to engage in behavior that others in the environment consider troublesome. These higher rates would not be considered a problem if the activity consisted of higher rates of house cleaning, completion of error-free homework, or plentiful assistance to a sibling on a project. However, high rates among the ADHD population frequently involves responding that competes with more advantageous behavior. In the future, researchers may find it useful to evaluate whether the high rates of activity hyperactive children display, are more or less likely to lead to advantageous outcomes.

Rule-Governed Behavior and Noncompliance in ADHD

Along with problems in attention, activity, and impulsivity, Barkley (1981, 1988, in-press) suggests that the ADHD have substantial difficulties in complying with rules. Rule-governed behavior refers to responding primarily determined by instructions, whereas contingency-shaped behavior refers to responding determined by its direct consequences (Skinner, 1969). In rule-governed behavior, compliance for following an instruction is reinforced. The actual rule- or, instruction-following episode, is composed of the delivery of an instruction, responding occasioned by the instruction, and a consequence delivered contingent upon compliance by the rule-giver (Cerutti, 1989). For instance, a child could learn to stay away from a hot stove by following a rule or by coming into contact with the stove and its natural consequences. In an instruction following episode a parent may tell a child to move away from the hot stove and then verbally praise the child for moving away. The child who learns to stay away from the stove by touching it and getting burned, learns from direct contingencies.

Barkley (in-press) describes studies showing that hyperactive children are less likely to comply with instructions than control subjects; use less developed self-verbalizations; and use verbalizations less during delayed reinforcement situations (see Gordon, 1979). Barkley (1988) concludes from these findings that the behavior of hyperactive children is better described as contingency-shaped, rather than rule-governed. However, contemporary accounts (Cerutti, 1989; Zettle & Hayes, 1982) of rule-governed behavior convincingly have argued that instructional control must be understood in terms of interactions between several simultaneously acting contingencies. Therefore, a finer grained analysis may help identify where the problems in rule-governed behavior develop, and perhaps show that the problems with rule-governed behavior arises from more fundamental difficulties.

To address the issue of fundamental factors, those situations that are least likely to result in compliance to rules must be identified. There may be at least three situations germane to hyperactive children: (1) When the outcome for following a rule is delayed; (2) When the outcome for following a rule has a low or moderate probability of occurring (or in the past has had a low probability of occurrence) in contrast to another more probable outcome concurrently available; (3) When the outcome for following a rule is immediate but too small to act as a reinforcer for the behavior it is specifying (e.g., the beneficial effects of consuming oat bran to lower cholesterol and reduce the risk of heart disease are small and only cumulatively beneficial after a long period of time) (Malott, 1989). Furthermore, these situations may occur in combinations to prevent rules from acquiring stimulus control over responding. For instance, a hyperactive child is told that if he sits quietly and works hard he will be nominated for the "student of the week" award. In this situation the child must wait a whole week to win the award and the probability of winning is uncertain since he has never won before; plus several other students are more likely candidates. In this situation delay to the reward is sizable and its likelihood uncertain. However, the child does know that if he sends a paper airplane soaring through class, there will be a high probability that he will receive an immediate reinforcer (classmates laughing and general attention from others). Not only is the reinforcer immediate and highly probable, it is also novel in comparison to the reinforcers that all of the other children receive, such as praise for on-task behavior.

<u>Supplemental</u> <u>Contingencies</u>. The variables responsible for causing noncompliance to rules in the hyperactive, may be similar to those variables responsible for causing problems in impulsivity and activity. It may that as Barkley (in-press) has suggested, hyperactive children may satiate to reinforcers more rapidly than

others. (Why there would be quicker response decrements to a particular reinforcer is unclear, although, it is conceivable that it could occur because the children have responded at higher rates which results in greater exposure to the reinforcer in a shorter time period.) Such basic differences in responding and reinforcement between hyperactive and typical children would have implications for responding in situations where reinforcers are delayed (whether or not a rule is given). As Skinner (1966) points out, sometimes rules or contingencies are unlikely to have an effect upon behavior, such as in situations where the contingencies for the behavior are quite delayed (e.g., eating oat bran to reduce cholesterol). When this is the case, the delayed contingencies need supplemental stimuli, such as laws, or the social behavior of others. Draeger et al. (1986) did show that the behavior of hyperactive children can come under the control of supplemental social stimuli when they demonstrated that the presence of an experimenter could reduce activity. However, it is possible that hyperactive children need supplemental contingencies to a greater extent than others.

Occasionally, the supplemental contingencies used during the delays are intrinsic to a setting, or provided by the organism. Logue and Mazur (1981) demonstrated that overhead colored delay lights functioned as conditioned reinforcers in an experimental setting with pigeons. In conditions when the delay lights were available during the experiment, the pigeons showed much more self-control than in conditions when they were not available. These lights probably gained their reinforcing properties by being contiguous to larger, delayed reinforcers. In addition, these lights could come to function as discriminative stimuli to interim behaviors, which an organism would perform during delays. Furthermore, these interim behaviors, could come to function as conditioned reinforcers to the delayed reinforcers, when there is temporal contiguity between the behaviors and the delayed reinforcer. Not only may the delayed reinforcers shape and strengthen intervening behaviors, but other mediating behaviors could occur that provide their own schedules of reinforcement. These intervening behaviors "help bridge the delay". The behaviors in which hyperactive children engage in during delays maybe less directly related to delayed contingencies (e.g., describing contingencies), and therefore, hyperactive children may not be as effective as typical children in supplementing the contingencies. Gordon (1979) already has presented evidence of differences that occur between the behaviors of hyperactive and control children during delays.

Contingency Descriptions. Hyperactive and typical children also may differ in their formulations of contingency descriptions; typical children may be better at describing delay contingencies. However, the ability to describe a contingency more accurately does not ensure that it will be followed more closely. Rarely do we formulate rules about our own behavior and use those rules to guide it (Shimoff, 1986; Skinner, 1969). Instead, the differences in contingency descriptions may reflect differences in exposure to the actual and/or supplemental contingencies, rather than the rules for a situation. Typical children may have experienced more reinforcement for compliance with instructions, to the point that their behavior is influenced conjointly by the delayed reinforcers and the rule. If the hyperactive children have not complied with instructions, they will not be exposed to the delayed contingencies; without this exposure they will be less likely to formulate or follow rules in the future. Therefore, hyperactive and typical children may differ in the formulation and following of contingency descriptions during delays (whether given by others or by self), but these differences are likely to be due to insufficient supplemental contingencies.

An analysis of the differences in contingency descriptions between hyperactive and nonhyperactive children remains pertinent, since contingency descriptions also are samples of behavior that are sensitive to contingencies (Shimoff, 1986). (However, as Shimoff suggests, contingency descriptions must be viewed as samples of behavior, rather than causes of behavior. Furthermore, these descriptions do not always reflect accurate depictions or interpretations by the subject of prior verbal behavior.) We may learn a great deal more about the "breakdown" in self-control and compliance with the hyperactive population by analyzing their contingency descriptions and compliance to rules in general; in doing so, we may find that compliance with instructions involves control by a set of contingencies more closely associated with the domain of self-control. Both rule-governed behavior and self-control consist of behavior specified instructions that lead to delayed contingencies, along with more immediate contingencies that produce compliance. Research remains to be done on the more molecular factors that influence reduced compliance.

Impulsivity

Although noncompliance to rules and high rates of activity may be the most widely recognized symptoms of ADHD, impulsivity may be the most problematic and core symptom of ADHD (Douglas, 1988; Kinsbourne & Swanson, 1979). Lack of impulse control, otherwise known as a lack of self-control, affects the hyperactive child's life in a number of realms. Ross and Ross (1982) describe the typical problems the hyperactive child encounters in academic settings:

> He makes many errors in both oral and written work because he does not stop to think, and may even start a task before being given the instructions. His impulsivity is irritating to his teacher because he does not seem to care about his mistakes; his hand is often the first to be raised in answer to a question, and the answer is almost always incorrect. Teachers are seldom tolerant of this behavior; the peer group picks up the teacher's attitude and tends to make fun of the child when he impulsively blurts out a clearly incorrect answer (p. 44).

This impulsive style can lead to a higher frequency of accidents (Hartsough & Lambert, 1985), underachievement in school, and social interaction problems (Ross & Ross, 1982). These difficulties in inhibiting responding are likely to continue into adulthood (Weiss & Hechtman, 1986). An adult with ADHD may be more likely to make impulsive business moves, blurt out offensive comments to others, cause more automobile accidents, and commit more crimes.

Although research in impulsivity may help us understand much about the problems associated with ADHD and help us develop effective treatment programs for them, there are difficulties in performing research in this area. To begin with, the measurement and identification of impulsivity is difficult due to substantial disagreements about its definition (Buss & Plomin, 1985; Campbell, 1987; Paulsen & Johnson, 1980). In the past, much of the research has been concerned with <u>cognitive impulsivity.</u> Cognitive impulsivity typically involves abstract situations and incorporates problem solving using discrimination skills, reflection, intelligence, and at times, remembering. One of the most commonly used type of tests is the Matching Familiar Figures Test (MFFT, Kagan, 1966). In this test, the child is required to match a picture from an array to a sample; one of the pictures is a replica, while the others vary just slightly from the sample. The child must look very closely at all of the features, on all of the pictures, to discriminate the differences accurately. The child's score is based on the mean response time to the first response and the total number of errors. However, the MFFT, and similar cognitive impulsivity tasks, may not provide adequate stimuli to identify impulsivity problems in the ADHD. Campbell, Szumowski, Ewing, Gluck, and Breaux (1982) found that cognitive measures of impulsivity failed to discriminate between preschool-age control and parent-identified children with behavior problems. Researchers (Buss & Plomin, 1975; Paulsen & Johnson, 1980) have suggested that cognitive impulsivity is a different "type" of impulsivity than that which involves delay of rewards. These experimenters have also indicated that the cognitive measures are actually measuring intelligence and not pure measures of impulsivity. These measures do not usually involve clear and/or "valuable" reinforcers. They are typically paper tasks that may not elicit the types of impulsivity that are most difficult for the ADHD child, such as inhibiting responding in a situation with an immediately available reinforcing stimulus. Completing a paper task while an experimenter is nearby, is very different from standing next to a classmate who is holding a shiny, red fire engine.

A few impulsivity studies have been completed that analyzed differences in responding between particular groups of children. A short longitudinal study (Golden, Montare, & Bridger, 1977) evaluated class differences in impulsive responding between working-class and middle-class boys. Although this research did not involve hyperactive or behavior problem children, its findings may still be relevant, since there tends to be a higher percentage of ADHD in working class environments. Golden et al. (1977) measured compliance to verbal commands in delay situations at 24, and then 30 months of age. The subjects participated in "games", where they were told to wait for varying delays before activating a train set in one condition, and reaching for a cookie in another condition. Subjects from middle class families delayed for longer periods of time on both tasks. Both groups delayed more at 30 months than at 24 months, with fairly consistent responding between the two delay tasks and across ages. The children delayed less when the game involved food (i.e., the cookie-delay-task) and less with greater delays. The authors suggested that the class differences reflected differences in parental control techniques. They speculated that working class parents rely more on nonverbal, physical methods while middle class parents are more likely to use language to control behavior. This hypothesis may be germane to the ADHD population, since ADHD children tend to fail to comply with verbal commands (Barkley, 1988) and exhibit less verbal behavior during delay tasks than typical children (Gordon, 1979).

Campbell et al. (1982) modified the Golden et al. (1977) cookie delay task to measure impulsivity differences between parent-identified problem 2- and 3-year old children and control subjects. Subjects were instructed to watch the experimenter hide a piece of animal cracker under one of three cups. They were then told to wait for the experimenter to ring a bell before looking for the cracker. The session consisted of six trials with delay intervals from 5 to 45 seconds, presented in random order. Responses were recorded as impulsive if the subjects picked up the cup or ate the cracker before the bell was sounded. The results demonstrated that the cookie-delay task could discriminate between parent-referred and control subjects. Furthermore, responding on three cognitive impulsivity tasks, including the Matching Familiar Figures Test, the Preschool Embedded Figures Test, and the Draw-A-Line Slowly Test, did not differentiate between the two groups.

These data show that measures that include reinforcing stimuli will be sensitive to differences in impulsivity.

Another study presented hyperactive and control subjects with clear-cut choices between short and long delays, with corresponding small and large reinforcers (Rapport, Tucker, DuPaul, Merlo, & Stoner, 1986). Subjects, between 6 and 8 years of age were given a choice between receiving one or two toys immediately after not doing any or minimal work, or receiving three or four toys after doing additional work and waiting two days. In another phase of the study, subjects were given the option of receiving all of the toys immediately after completing 0-25 problems, with the number of toys earned depending on the numbers of problems completed. The data showed that a significantly larger number of hyperactive children preferred the immediate rewards over the delayed ones, in comparison to control children. During the phase where immediate rewards were available after work completion, an equivalent number of hyperactive and control subjects chose to complete a larger number of problems and receive the greater number of rewards. This study shows that the hyperactive children were more sensitive to delays, and less so to amounts of reward, than control children.

The preceding studies (i.e., Campbell et al., 1982; Golden et al., 1977; Rapport, et al., 1986) demonstrate that it is possible to study observable differences in at least one facet of self-control. We may learn more about the specific nature of the impulsivity difficulties ADHD children exhibit through the procedures used in those studies.

The Importance of Studying Self-Control in the ADHD Population

There are many advantages to studying this core symptom of ADHD. An examination of basic self-control differences between hyperactive and other children would give us a better understanding of the disorder, may allow us to evaluate the current motivational and self-regulatory theories of ADHD (Douglas, Barr, Amin, O'Neill, & Britton, 1988; Haenlin & Caul, 1987), and help us devise therapeutic interventions.

There is clearly a need for objective, yet individually tailored measures of self-control that take individual learning and physiological histories of reinforcement into account. This translates into the use of child-selected stimuli in assessments (optimally the best stimuli would be those that actually have been shown to function as reinforcers). Contextually valid measures of impulsivity in ADHD children have been far and few between.

Procedures from the operant literature offer a method of analyzing and measuring self-control that takes the individual's behavior and the context into account. The operant procedures use choice paradigms that are objective, easy to measure, and allow the use of individually specified stimuli. The following section will discuss in greater detail the concept of analyzing impulsivity as choice behavior.

CHAPTER 2

CHOICE IN OPERANT LITERATURE

"Life is a bowl of concurrent schedules" (Donahoe, 1982) and hyperactive children may prefer to select concurrents that are on the top of the bowl, rather than probing through the bowl to the most delectable ones. Concurrent schedules are defined as situations "in which behavior is free to alternate continuously between two or more alternatives, and in which consequences for choosing each alternative occur occasionally..." (McDowell, 1988, p. 96). Choices are said to be made when an organism performs a response that leads to one reinforcer instead of another. It is difficult to think of any behavior that is not actually choice behavior; almost all behavior occurs in contrast to other available behaviors. For example, one alternative for a child is to listen intently to his teacher, while another concurrently available alternative is to pull his classmate's pigtails.

Operant researchers are particularly interested in how organisms distribute their behavior according to available reinforcers. The matching law and the delay-reduction hypothesis are two descriptive/predictive model of choice behavior that have been applied to self-control situations (e.g., Ainslie, 1974; Fantino, 1966; Mazur & Logue, 1978; Rachlin & Green, 1972). Both models define self-control as the choice of larger more delayed reinforcers over smaller more immediate ones. Most researchers use concurrent-chain or concurrent discrete trial procedures to measure preference. A concurrent-chain procedure involves the presentation of two or more concurrently available alternatives in which the subject chooses a reinforcer during the "initial link" phase. The consequence of the choice during the initial link is the onset of another schedule, the "terminal link", which then leads to access of a primary reinforcer. Choice for the reinforcer associated with each terminal link is determined by the distribution of responses in the initial link (Catania, 1984). Access to the next initial link and trial begins after reinforcer "handling time" (a period in which the subject has time to make a consummatory response). Discrete trial procedures (e.g., Mazur & Logue, 1978; Schweitzer & Sulzer-Azaroff, 1989) also involve the presentation of two or more alternatives but may or may not have the initial and terminal link (frequently there is just a single choice between two schedules that leads directly to the primary reinforcer). Typically a postreinforcer time (in addition to the handling time) is added to trials in which the immediate, smaller reinforcer is chosen. The length of this postreinforcer delay is at least the length of the prereinforcer delay to the larger, more delayed alternative. Intertrial intervals (time between onset of successive trials) are held constant so that the overall rate of reinforcement does not depend on the choice behavior of the subject. If the intertrial intervals are not made equivalent, the subject could potentially earn more by choosing the immediate, smaller reward repeatedly. Behavioral researchers have used these procedures to analyze the effects of a number of variables on choice behavior, including the delay to the reinforcer, the amount of reinforcement available, stimuli available during delays, and species of the organism (Fantino, 1969; Grosch & Neuringer, 1981; Logue & Mazur, 1981; Rodriguez & Logue, 1988; Rachlin & Green, 1972). In experiments involving human subjects, researchers also have looked at the role of various types of covert and overt verbalizations, and the effects of developmental and sex differences on choice behavior (Chavarro & Logue, 1987; Miller, Weinstein, Karniol, 1978; Mischel, Ebbesen, & Zeiss, 1972; Sonuga-Barke, Lea, & Webley, 1989a).

The Matching Law Description of Behavior

Studies have shown that the choice behavior of an organism could be described by the matching law (Herrnstein, 1970), which predicts a match between the proportion of responses and the proportion of reinforcers for that response. A modification of the matching law incorporates delay of reinforcement as a variable as well (Baum & Rachlin, 1969). In Baum and Rachlin's (1969) revision, the relative preference for a response is proportional to the relative value of the consequence for that response, "value" being a function of amount, rate, and immediacy of reinforcement.

Research with pigeons (Ainslie, 1975; Chung & Herrnstein, 1967), adult humans (Navarick, 1982; Solnick, Kannenberg, Eckerman, & Waller, 1980) and children (Schweitzer & Sulzer-Azaroff, 1988) has shown that the length of the delay between the response and the reinforcer can affect choice, with the effectiveness of the reinforcer declining as the delay increases. Thus, when the delay from the reinforcer to the response is short, choice for the smaller reinforcer is more probable than choice for a more delayed larger reinforcer. The matching law predicts such a reversal in preference from the larger, more delayed reinforcer to the smaller one as delays to both reinforcers decrease (Ainslie & Herrnstein, 1981; Green, Fisher, Perlow, & Sherman, 1981). Experiments with pigeons have illustrated this reversal in choice by showing that subjects tend to select the smaller, less delayed reinforcers, even when offered the alternative of larger reinforcers that are available after only a relatively brief period of time (Ainslie, 1974; Ainslie & Herrnstein, 1981; Green et al., 1981; Green & Snyderman, 1980). In these studies, responding is affected more by the length of the delay than amount of reinforcement available.

Experiments with adult human subjects have been more challenging, because with positive reinforcement adults tend to demonstrate self-control [or "maximization" by always choosing the larger, more delayed reinforcer (Logue, 1989)], regardless of the delays, at least over the delay intervals used in laboratory studies (Logue, Peña-Correal, Rodriguez, & Kabela, 1986; Millar & Navarick, 1984). Experiments that used positive reinforcers and were less likely to show impulsive responding in adult subjects, used access to a video or points exchangeable for money after a session, as the reinforcers (Logue et al., 1986; Millar & Navarick, 1984). Only 40% of the subjects in the Millar & Navarick (1984) study demonstrated impulsive responding, while subjects from the Logue et al. (1986) study consistently showed self-control by routinely selecting the larger, more delayed reinforcers. Logue et al. (1986) suggested that the subjects used maximization strategies during the sessions and that adults are more sensitive to reinforcer amount than reinforcer delay. The adults may have responded more impulsively, however, if they were exposed to more currently valued reinforcers during the sessions, such as food, or the choice of access to a Ferrari over a Honda. Subjects may have found the stimuli used as reinforcers in the Logue et al. (1986) study insufficiently powerful as reinforcers; subjects earned approximately $2.00 for sessions that lasted from 30 minutes up to a maximum of 90 minutes. If "the stakes were high enough" adults probably would respond impulsively in some situations. (In fact in some situations it is more advantageous for all organisms to respond impulsively.) Indeed, Logue and King (in press) found a situation in which female undergraduate subjects demonstrate impulsivity; female subjects that are dieting are likely to be impulsive when juice is used as a reinforcer. Subjects do respond impulsively to negative reinforcement procedures (Navarick, 1982; Solnick et al., 1980) or time "discounting procedures", where points accumulated are decreased at a steady rate during reinforcement delays, (Rodriguez & Logue, 1988).

<u>Extraneous Sources of Reinforcement-R_e</u>

In addition to varying the amount and delay to reinforcement, experimenters have discussed the effect of extraneous reinforcement on responding manipulated by the experimenter (de Villiers, 1977; Herrnstein, 1970; Herrnstein & Loveland, 1974; McDowell, 1988). Herrnstein (1970) suggested a modification of the matching law to include a parameter known as r_o, which was then renamed as r_e (Herrnstein & Loveland, 1974). This expression, r_e, represents the unknown aggregate of reinforcement that the organism receives for all other behaviors in an experimental setting other than those that the experimenter is directly manipulating. Herrnstein (1970) suggests that a subject's environment always contains some activities to engage in, no matter how impoverished the experimenter tries to make the environment. These other alternative behaviors may include a range of responses, including instinctive behavior such as preening, scratching, or yawning. In children it may include any number of behaviors as well, for example, nail biting, shoe tying, or thinking about a television show watched the night before. As Herrnstein (1970) suggests, alternative responses are always available, whether or not the experimenter provides them. (The same could be said by a parent or teacher about the availability of alternative responses. Problems occur when the alternative responses and reinforcers interfere with behavior desired by the parent or teacher.)

These alternative reinforcers and responses may also affect the value of the reinforcement that the experimenter is providing for particular responses (McDowell, 1988). When the environment is rich with reinforcement for responses other than those targeted by the experimenter, the rate of responding for the target response will be low. Similarly, if the environment is impoverished, the response rate of the target behavior will be high. For instance, a child is more likely to sit in his seat during class if there is little else in the room to distract him, (or little else that he finds reinforcing). However, on days when there has been a new shipment of toys, the child is less likely to sit in his seat and more likely to spend time inspecting the new toys. This view of reinforcement says that behavior is affected not only by the rate of contingent reinforcement, but also by the rate of concurrently available reinforcement. This version of the matching law promotes a contextual view of how the total amount of reinforcement available in an environment can affect a specific behavior.

Although much of the self-control and choice data are described quite well by a model such as the matching law, it must be remembered that such models have limited power. These models are quite good at describing behavior in some situations, but they can only describe behavior and not explain it. As Rachlin, Green, and Tormey (1988) state, matching is not a "fundamental law of human nature" (p. 122), but a tool to analyze the structure of behavior. Although the matching principle may help us describe how children distribute their behavior according to reinforcement available, a more molecular analysis is still required to determine why the behavior is distributed in a particular way.

Variations in Self-Control Due to Individual Differences

Developmental Differences in Self-Control Behavior

There is also a small, but growing literature on how variables other than reinforcement value affect choice in children. Research demonstrates that self-control not only is influenced by the amount and delay of reinforcement available, but also by a subject's age and verbal ability (Miller, Weinstein, & Karniol, 1978; Sarafino, Russo, Barker, Consentino, & Titus, 1982; Sonuga-Barke et al., 1989). Studies in these areas are particularly pertinent to the treatment of hyperactive children, since they are often considered developmentally immature in both nonverbal and verbal behavior. In general, young children tend to choose smaller, less delayed reinforcers (Mischel & Mischel, 1983; Miller et al., 1978; Sarafino et al., 1982). Sarafino et al. (1982) showed that fourth graders were more likely to select larger, delayed reinforcers than were kindergartners. Miller et al. (1978) found that third grade children were more likely to show self-control than kindergartners in delay conditions where they were <u>not</u> instructed to verbalize. Developmental differences were not obtained during other conditions where the experimenters gave the subjects overt strategies to perform. The authors hypothesized that the older children used covert verbalizations during the delays.

In contrast, Schwarz, Schrager, and Lyons (1983) and Crooks (1977) did not find developmental differences in choice. Schwarz et al. (1983) examined differences in choice between 3,4, and 5 year-old children and found that all ages were equally sensitive to delay times of no delay, 7 hours, and 1 day. Differences in the choice behavior might have surfaced, however, if the experiment contrasted less salient delay times over repeated trials. Crooks (1977) found no differences in preference between 6 to 7 year old and 10 to 12 year old subjects, for access to chocolate bars varying in size and available immediately or in a week. Again, as in the Schwarz et al. (1983) experiment, the differences in the delays was probably extremely salient to all age groups and smaller delays may have obtained different results.

In a recent study Sonuga-Barke et al. (1989a) found differences between female subjects at the ages of 4, 6, 9 and 12 for choice in a concurrent-chain schedule across varying delays. The schedule was composed of VI 10 s initial links and terminal links of 20, 30, 40, or 50 s (delays varied between sessions) followed by two tokens versus a 10 s delay followed by one token. In this concurrent-chain, a new trial would start as soon as the reinforcers for the previous trials had been dispensed. At delays of 20 and 30 s, subjects could earn the most tokens over the session by choosing the 20 or 30 s delay over the 10 s alternative. The 10 and 40 s delays resulted in an equivalent number of tokens, while the 10 s alternative was more profitable than the 50 s delay. All 12 year-old subjects, and half of the 4 year old subjects demonstrated increasing preference for small rewards, when the delay to the larger rewards was no longer adaptive (at 50 s). At shorter delays the 12 year olds chose the longer, larger reward. Subjects at 6 and 9 years, and half of the 4 year olds, showed a preference for the larger, more delayed reward at all delay periods, including the 50 s delay. Thus, overall the 12 year olds and half of the 4 year olds, were sensitive to the reward delay and size. Although half of the 4 year old group and all of the 12 year old group exhibited similar responding, the authors interpreted their behavior in different ways. According to Sonuga et al. (1989a), children develop a sensitivity to the joint effects of both delay and frequency of reinforcement, so that with maturity they behave adaptively, even if that requires a reversal of preference for larger delayed rewards. Therefore, the experimenters suggested that the 4 year old subjects were responding impulsively, while the 12 year old subjects were responding optimally, when delays were long and they selected the immediate small reinforcers.

Sonuga-Barke, Lea, and Webley (1989b) performed two additional experiments to test developmental differences in subjects' sensitivity to prereinforcer delay and reinforcer magnitude. These findings support the earlier ones (Sonuga-Barke et al., 1989a) in that most younger children's responding (6 and 9 years) was governed by reward size and not prereward delay. The way they accomplished this was to test the differences in degree of insensitivity to delay between 6 and 12 year old children. A clever titration procedure was used whereby repeated choice of the large reinforcer led to increased delay times, whereas repeated choice of the small reinforcer reduced the delay times of the large reinforcer. Thus, the optimal strategy would be to distribute responding between the two alternatives to prevent the delays from increasing while gaining the maximum amount of reinforcement available. Most 6 year old children only responded to reinforcer size and consequently continuously increased the length of the prereinforcer delay. Some 6 year old subjects continued to choose the delayed reinforcer at delays of 10 minutes. Most of the 12 year old subjects learned to alternate their responding between the small and large reinforcers throughout each session. Their responding was a function of reinforcer delay and size, and therefore, more profitable over the session. Sonuga-Barke et al. (1989b) suggest a developmental theory of social control to explain the differences in responding. They hypothesize that younger children believe that larger, delayed reinforcers are deemed socially more virtuous. This theory has interesting implications for possible differences in self-control between ADHD and typical children. One prominent symptom of the ADHD population is their lack of sensitivity to social contingencies. If choice for larger, delayed reinforcers is partially a function of social consequences, one would expect lower rates of self-control responding in ADHD children due to their insensitivity to the social consequences. It seems unlikely that social contingencies are responsible for the severity of the self-control problems in ADHD, however, they may play an important role.

Verbal Ability

Experimental findings also have revealed that developmental differences in self-control may be affected by the behaviors engaged in during delay periods. For example the use and content of self-statements may influence self-control. Studies have found that children who are told to specify the consequences (contingency-specifying rules) of waiting in task-centered statements, will choose to wait longer than children who just wait, use nursery rhymes, or reward-centered statements (Anderson & Moreland, 1982; Hartig & Kanfer, 1973; Toner, 1981). As children's verbal abilities develop, they are probably more likely to use these types of statements. In addition, research has shown that the use of irrelevant distractors (e.g., singing, playing games with hands or feet) during delay times, seems to facilitate waiting (Mischel & Ebbesen, 1970; Mischel, Ebbesen, & Zeiss, 1972). Mischel et al. (1972) found that older children tend to use distractors that are more likely to lead to choice for larger, delayed reinforcers. These distractors may be providing another source of reinforcement or function as conditioned reinforcers during delay times. Evidence suggests (Gordon, 1979) that hyperactive children may engage in less mature delay behaviors.

<u>Time Estimation of Delays</u>

There is some speculation that the ability to estimate time may be related to one's ability to choose the most advantageous schedule of reinforcement. Logue et al. (1987) found during postexperiment questioning that adult subjects counted during delays to the two alternatives in a self-control task. The authors hypothesized that the subjects' ability to count during the delays enabled them to determine which was the more profitable alternative. Logue et al. (1987) suggested that subjects' ability to count and form rules may be one reason why adults typically show self-control during these types of experiments.

Sonuga-Barke et al. (1989a) also found a possible relationship between subjects' ability to esitmate delays and their performance in a self-control situation. In one case, a 9 year old subject altered her preference for the larger, delayed reward to the smaller, more immediate reward (which was actually more profitable at times in this procedure) after she began counting the length of each delay period associated with each reward alternative. During postsession questioning, the subject reported that she chose the more profitable schedule because "... it got through quicker and I could get more" (p. 82). The authors suggest that the behavior of the 12 year old children, who typically chose the most advantageous schedule, was determined by their ability to verbally estimate the rate of reward.

Hyperactive children have been found to be less accurate than other children in their ability to estimate time (Capella, Gentile, & Juliano, 1977). Hyperactive and normal children from 7-12 year olds were asked to estimate time intervals ranging from 7-60 s. The results showed that hyperactive children made larger estimation errors between the actual elapsed time and their estimations; that longer intervals led to larger errors in both groups; and that the hyperactive subjects' errors were larger in comparison to normal subjects as the time intervals increased. Hyperactive children may be at a severe disadvantage if Logue et al. (1987) and Sonuga-Barke et al., (1989a) are correct that there is a positive relationship between the ability to verbally estimate time and show self-control.

Sex Differences in Self-Control

Differences in the sex of preschool subjects have also been shown to affect self-control responding. Chavarro and Logue (1987) examined choice responding between 3 and 4 year-old boys and girls. At both ages, the boys selected the smaller, more immediate reinforcers more often. These data are particularly relevant to the ADHD population since the majority of children identified as hyperactive are males.

Procedures to Increase Self-Control Responding

Procedures that have been effective in influencing choice behavior include training more advantageous responses and altering the experimental setting. Studies have demonstrated that self-control can be increased in pigeons and impulsive children by systematically increasing or decreasing delays to reinforcers in a gradual manner (Ferster, 1953; Mazur & Logue, 1978; Schweitzer & Sulzer-Azaroff, 1988). Other procedures effective in increasing self-control have required organisms to commit in advance to later choices for large reinforcers (Ainslie, 1974; Rachlin & Green, 1972).

Other studies have examined the effects of adding additional sources of reinforcement or distractors on choice (Fantino & Dunn, 1983; Grosch & Neuringer, 1981; Mischel et al., 1972; Logue, King, Chavarro, & Volpe, in press). Grosch and Neuringer (1981) replicated a study that Mischel et al. (1972) performed with children, on pigeons, and obtained similar results. The findings (Grosch & Neuringer, 1981) demonstrated that the addition of an alternative response key and reinforcement during delays, results in increases in self-control responding. Logue et al. (in press) compared choice in adult females between situations in which music was or was not available throughout the experimental session. The investigators permitted a group of subjects to listen to a radio station during sessions with concurrent variable-interval schedules, in which delays and amounts of reinforcers were varied with points exchangeable for money as reinforcers. Another group did not have access to the radio and was exposed to the same schedule parameters. The responding of subjects who did have access to the music was closer to indifference than the subjects from the other group, who showed more impulsive responding. Overall, the studies reviewed in this section suggest self-control will be affected by access to additional sources of reinforcement.

Advantages of Employing an Operant Analysis in the Study of ADHD

There are many advantages to applying the operant methodology of analyzing choice behavior in order to examine self-control problems of the ADHD population. First, investigators in the operant area have developed objective and measurable definitions of self-control. This insures some standardization in the process of studying self-control, thereby allowing results across specific conditions and experiments to be extrapolated more readily.

Second, the operant methodology analyzes relationships between environment and behavior, and is therefore well suited to investigating the situational differences that the ADHD population exhibits. The behavioral research that uses concurrent schedules provides an ideal model for analyzing the problem behavior of this population. The ADHD population may differs from its peers in that the former makes choices based on immediacy of reinforcement while the latter make choices based on the amount of reinforcement as well. Most likely ADHD children engage at a higher rate, in behaviors that ultimately will be disapproved of by those in their environment--behaviors typically disadvantageous to them in the long run. Laboratory choice procedures are ideal analogues for analyzing youngsters' selection among more or less advantageous options.

Third, a preexisting operant literature concerned with how particular organisms respond differentially to delay versus amount of reinforcement provides a valuable foundation for later work. Again, this knowledge is relevant to the study of the ADHD population, as this group is so often characterized as being overly sensitive to delays.

Furthermore, research pertinent to the matching law already has established a methodology to analyze issues in self-control--of special value in the present instance. Those investigators also have generated rules enabling predictions of how responding will be distributed among reinforcers varying in size and delays.

The growing conceptual and experimental-operant literature analyzing the effect of concurrent tasks on choice also may be relevant to interpreting and modifying the responding of ADHD children. That literature suggests that self-control can be altered if adaptive sources of reinforcement are concurrently available. For the alternatives to be adaptive, they must promote, not interfere with choice of the larger, delayed reinforcers (e.g., making self-statements or playing games--behavior that has its own schedule of reinforcement or serve as conditioned reinforcers.)

The present study attempted to integrate the findings and methods of the choice research in an effort to better understand self-control differences between typical and ADHD boys. More specifically, this experiment attempted to assess differences in the proportion of choice of larger, delayed over smaller, immediate reinforcers as well as a number of other measurable differences in the responding of ADHD and typical boys in situations with and without concurrently available tasks.

CHAPTER 3

METHOD

Subjects

Human Subject Committees at the University of Massachusetts Medical Center (UMMC) and at the University of Massachusetts, Amherst (UMASS, Amherst) gave approval for the study. A total of 18 subjects, 10 diagnosed as having ADHD and 8 typical boys served as subjects. (The data of two normal subjects were later excluded because these boys showed unusual signs of distress in response to their learning that their parents were going to leave the clinic waiting room while the experiment was ongoing. For example, one parent told the subject she was going upstairs with his siblings to the cafeteria to get lunch. In the next phase, the subject's choice between immediate and delayed rewards changed dramatically in comparison to prior sessions that day.) Children with neurological impairments, IQs below the normal range for their age, language deficits, or psychopathology were excluded from the study. The mean age for the ADHD group was 6 years and 1 month with a range from 5 years and 3 months to 6 years and 9 months, while the mean age for the typical boys was 6 years and 3 months with a range from 5 years and 3 months to 7 years and one month. Based on the Hollingshead Occupation Scale of Social Economic Standing (SES) (Hollingshead, 1975) the parents of the ADHD group had a mean SES average of 66 (one parent was unemployed and lowered the average by 7 points for this group), with the typical group of parents averaging a mean SES of 80. (The lowest possible score on the scale is 10 and the highest is 90.) All subjects scored within the normal range of intelligence. The mean IQ was 110.61 for the ADHD boys and 113.75 for the typical boys. All but eight of the subjects' IQs had been obtained through previous testing on complete or partial Stanford-Binet Intelligence Scale, Fourth Edition (SBIS:FE) tests, or the revised Weschler Intelligence Scale for Children (WISC-R) within the past year. The experimenter administered the Vocabulary, Quantitative, and Pattern Analysis subtests of the SBIS:FE to obtain partial composite IQs for seven of the eight remaining subjects. While a composite IQ was derived for the others via the Arithmetic, Block Design, and Vocabulary subtests of the WISC-R. All subjects tested on the SBIS:FE had test composites that included the Vocabulary and Pattern Analysis tests. Eight of the subjects tested on the SBIS:FE had composites that included the Quantitative test. All of the other subjects tested on the SBIS:FE had the full test for their age. The Pattern Analysis and Vocabulary tests have the highest median intercorrelations of the areas they represent, with a correlation of .47 between the Vocabulary and Verbal Reasoning area and a correlation on .65 between Pattern Analysis and the Abstract/Visual Reasoning area

(Thorndike, Hagen, Sattler, 1986). Although most subjects had more than two tests within the SBIS:FE, the 2-test composite is considered acceptable for screening purposes. The reliability indices for a 2-test composite for age 5 is .91, and for age 6, .89 (Thorndike, Hagen, & Sattler, 1986). Statistical analyses indicated that there were no significant differences in age, SES, or IQ between the two groups of subjects.

The ADHD group was recruited through the ADHD Diagnostic Clinic at the University of Massachusetts Medical Center. The experimenter solicited the parents of previously diagnosed children by telephone and letters. Parents of typical children were recruited through clinic records of previous research participants at the ADHD Clinic and Department of Psychology, and through advertisements posted in the Medical Center and at local pediatric clinics. Parents were given $10.00 per session, with $2.00 delivered on the first day and the balance of $18.00 on the second day.

Parents of the subjects signed informed consent statements and viewed the testing room and apparatus before testing began on the first day. Parents of the typical subjects also completed authorization for release of behavioral/academic forms to be mailed to subjects' teachers for further information on the subjects' functioning. The experimenter photocopied these forms and sent behavior rating scales to the subjects' teachers.

Parents and teachers of the typical children completed Child Behavior Checklists (CBCL, Achenbach & Edelbrock, 1983) and behavior checklists listing the 14 items on the DSM-III-R diagnostic criteria. The CBCL lists 113 items representative of child psychopathology and groups the items according to various child disorders (e.g., Social Withdrawal, Hyperactive, Obsessive-compulsive). Norms are available for 3-16 year old boys and girls. All typical subjects fell within the normal range on all of the CBCL factors.

The DSM-III-R checklist is rated on a 4-point scale (not at all, just a little, pretty much, very much) requiring the responder to rate how closely each dimension of ADHD describes the child in question. Norms for the scale are available for 6-12 year old children of both sexes (DuPaul, 1990). This scale yields 3 scores, an overall ADHD score, an inattention-hyperactivity factor, and an impulsivity-hyperactivity factor. Again, all subjects' scores fell within the normal range on this scale.

Children in the ADHD sample had been clinically diagnosed at the ADHD Clinic at the University of Massachusetts Medical Center based on the following criteria: (1) Parents and/or teacher reports of problems in rates of activity, duration of attention, excessive impulsivity and noncompliance; (2) Symptom onset before six years of age; (3) Disturbance of at least 12 months in which the symptoms were present; (4) Scores on the Hyperactive/Immaturity scale of the CBCL at 93% or above (indicating that the child displayed more characteristics of hyperactivity than 93% of his same aged-peers); a score of 8 or more out of 16 (2 SDs above the mean) on the Home Situations Questionnaire (Barkley, 1981), which is a parent-report measure of the severity and frequency of the occurrence of behavior problems in specific situations (e.g., during meals, while watching television); and a score of 8 out of 14 on the DSM-III-R criteria checklist; (5) The absence of a diagnosis of autism or pervasive developmental disorder, psychosis, seizures, deafness, blindness, cerebral palsy, significant language impairment, or apparent brain damage diagnosed through medical history or behavioral observation.

Subjects who used psychotropic medication also were excluded, with the exception of methylphenidate (Ritalin), since it has a short half-life. Two of the ADHD subjects were regularly taking methylphenidate, but at the experimenter's request did not ingest the medication for 24 hours before the testing sessions. Of the ADHD subjects, 6 of the 10 carried a dual diagnosis of Oppositional Defiant Disorder (ODD), a disorder of "negativistic, hostile, and defiant behavior without the more serious violations of the basic rights of others that are seen in Conduct Disorder" (p. 56, DSM-III-R, 1987).

It is not unusual for ADHD children between the ages of 4 to 7 years to display features of ODD; frequently it is the defiant and aggressive behaviors that first cause these children to be noticed and motivate their parents and teachers to seek out professional help.

Apparatus and Materials

On the desk at which subjects' sat, was a slope-paneled blue, wooden console, 54.5 cm wide, 47 cm high, 35 cm deep at the top and 45.5 cm deep on the bottom (see Figure 1). A BRS-Foringer (model ND-601) nickel-coin dispenser was positioned on the lower right side of the apparatus beneath a 15 cm X 15 cm utility speaker. A peg-board with 36 holes in it (to allow sound to emanate) was nailed over the speaker to protect it from potential child-inflicted damage. A mounted IEE-24 volt stimulus projector was centered in the middle of the apparatus. The projector illuminated 3 stimulus displays through green, amber and purple filters of unspecified transmission properties (Edmund Scientific) 7.5 cm above two metal pull handles and a push button. The center display of the three illuminated a green light to signal trial onset. The left and right displays concurrently illuminated amber and purple lights. The colors randomly alternated from trial to trial with the amber filter illuminated during the long delay and the purple light during the short delay. The push button below the center

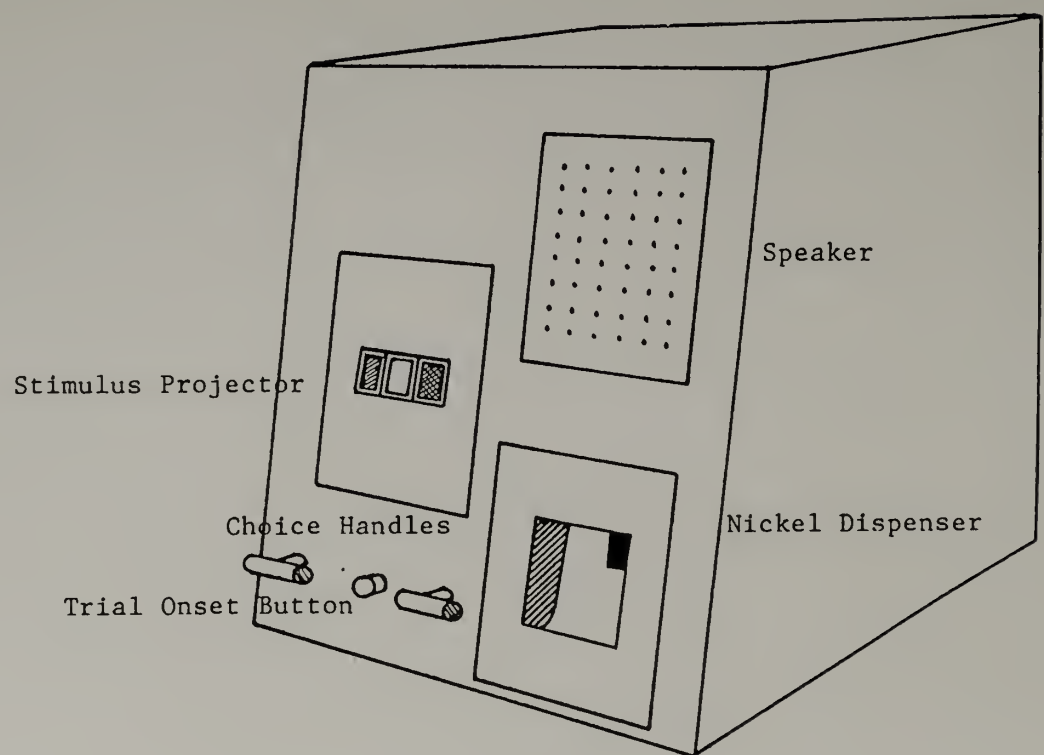

Fig. 1. Drawing of the apparatus.

stimulus panel was illuminated at the onset of each trial and had to be pushed to initiate each new trial. Two metal handles 7.5 cm long were placed below the left and right panels of the stimulus projector and required a weight of 600 grams to operate them. Subjects pulled the handle under the colored light associated with the reinforcer delay and amount they selected. A muffled, ambulance-like buzzer (Radio Shack-273-070) of CS-66 decibels, placed within the apparatus sounded upon trial onset and stopped once the subjects pushed in the onset button. During the B phases 10 s of tape recorded music could be activated by pushing in a red push-button attached to the console on a 105 cm long heavily insulated electrical cord.

A plastic wind-up bank shaped like an apple (The Last Wound-Up-527) was used to permit the children to store their nickels. The weight of a coin on a small button on the apple's top caused a plastic "worm" to come out of the apple and pull the coin within the bank. To prevent the subjects from opening the bank during the sessions, it was mounted on a 21 cm X 18 cm plywood platform and C-clamped onto the table before each session. The plywood had a hole drilled into it directly beneath the bank's bottom opening to permit access through the platform when it was unclamped.

Two small toys were available throughout the B phase as well, a 3 cm wide wooden top and a tin plunger-driven spin toy that could produce a variety of colored sparks when activated. Both toys were placed on the desk to the right of the apparatus and within arm's reach.

A standard, hand-operated stop watch was used to record subjects' nonverbal estimations of time delays. Two Timex Motion Recorders were used to measure both wrist and ankle activity. The wrist actometer was worn on the preferred wrist, while the ankle actometer was worn on the opposite ankle. A sweatband covered the wrist actometer to prevent damage to the clock face and reduce the likelihood of subjects' tampering with the watch.

A pool of seven audio tape selections were available for use during Phase B. Two of the tapes played recordings of popular children's music, while each of the other five tapes played a different popular rock song repeated several times on its respective tape. The songs on the children's music tapes, shorter in duration, played 4 songs in sequence repeatedly throughout those tapes.

An array of tangible rewards included decorated pencils, cartoon and animal shape erasers, stickers, superballs, baseball cards, story-books, number toys, plastic sunglasses, frisbees, toy race cars and airplanes, crayons, and others. Six of these were displayed at a time prior to each phase in a 20.5 cm X 27 cm plastic tray with dividers, and were rotated to ensure that at least three new items were included on each presentation.

A Zenith computer with software written on Microsoft Quickbasic 4.0, was placed in an adjacent room. It controlled all experimental conditions, the tape recorder, and recorded the children's responses on the manipulanda. The program is available through the author.

A photocopied picture-rating scale contained a 5-point scale showing faces displaying varying degrees of pleasure, disinterest, or displeasure with the task. (see Figure 2).

Setting

All of the ADHD and six of the typical subjects were tested in a room at the Ambulatory Psychiatry clinic at the UMMC. A standard waiting room for the adults was within the Clinic. The apparatus sat on a desk in the back of the testing room and the wall behind it was decorated with an animal poster. A round table was located 150 cm to the right of the desk and three chairs were positioned against the same wall, which held an observational window. Two chairs were positioned against the third wall, while an empty shelving unit and coffee table were located against the fourth wall.

The other two typical subjects were tested in a laboratory room in the Department of Psychology at the University of Massachusetts at Amherst. A similar desk held the apparatus under an animal poster, in a room that also had extra chairs positioned against an observational window, and a table in close proximity to the desk. The

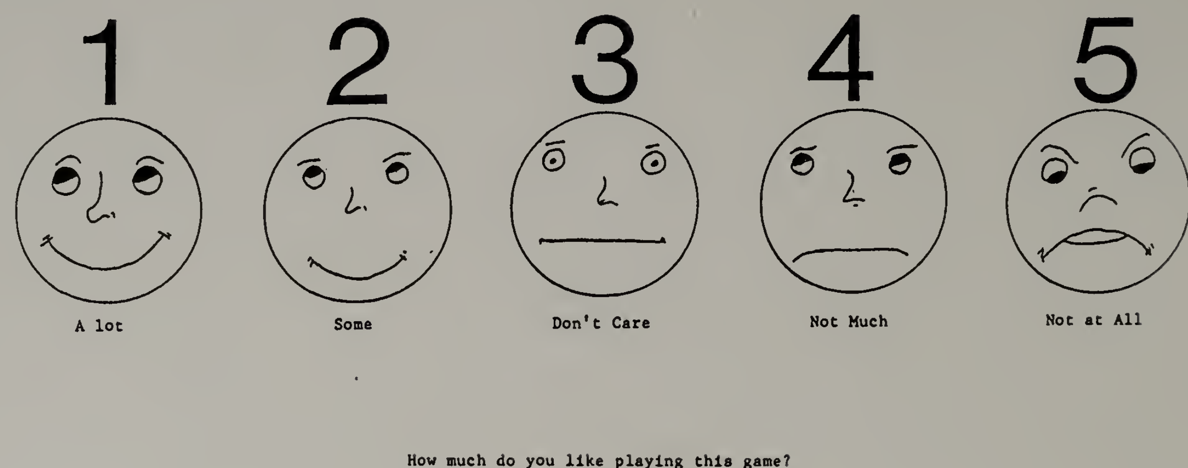

Fig. 2. Rating of enjoyment scale.

Amherst setting also had a waiting room for adults. The computer and videotape recording machines were stored in adjacent rooms in both testing sites. A clock in the UMMC setting was covered with cardboard to avoid its serving as a cue during subjects' testing. (None of the children wore watches or any jewelry during the testing.)

Measures

A variety of systems were used to collect data on several dependent measures. Table 1 shows each response category with its corresponding measurement system. The computer collected trial by trial data on each subject's choice of the lever that was paired with either the delayed (3 nickels) or the immediate reinforcer(s) (1 nickel); latency times to initiate a trial after a siren and lights signaled trial availability; latency times to choose between the delayed and immediate reinforcers after the initial response had been made; and response rates on the manipulanda (button and handles) at times when they were nonfunctional (e.g., rate of pulls on the handle after the choice had been made). The nonfunctional response rates were divided into two categories, terminal-link responses and other responses. Terminal link responses were subsequent pulls on the handle that was used to select a reinforcement schedule (immediate or delayed) during that trial. Other responses were pushes of the initial link button anytime other than during the

Table 1

Data Collection Methods for Dependent Measures

Response	Data Collection Method
Choice for large reinforcer	Computer
Initial link latency	Computer
Terminal link latency	Computer
Terminal link responses on nonfunctional manipulanda	Computer
Other responses on nonfunctional manipulanda	Computer
Rate of music responses	Computer
Rate of spin toy responses	Videotape
Rate of table top toy responses	Videotape
Holding the music cord	Videotape
Enjoyment of phase	Picture rating scale
Nonverbal delay estimation	Stopwatch
Rates of activity	
Wrist and ankle	Actometer
Fidgeting	Videotape
Out of seat	Videotape
Contingency descriptions	Verbal descriptions
Verbal estimation of delay	Verbal description

initial link phase of the trial and pulls on the handle that were not used to select a schedule within that trial.

At the end of all three phases on Day 1 and 2, each subject estimated the length of the delay for the immediate and delayed reinforcer by pressing in a button for the duration of time he thought corresponded to each delay. The experimenter used a hand-held stopwatch to record the time estimations.

Rates of activity were measured via two systems, the average rate of wrist and ankle actometer movement and by videotapes coded on a 15 s partial-interval system whereby any occurrence during the interval was scored as an occurrence. Two research assistants blind to the hypothesis of the study and the identity of the subjects' group scored the videotapes. The categories on the videotape included fidgeting and out of seat behavior and were adapted from Barkley (1988) (see Appendix B for complete definitions). The observers scored the tapes with the aid of an audiotape which signaled the beginning of each 15 s trial. The first three observational categories described were adapted from the Restricted Academic Situations Task (Barkley, 1988), an assessment procedure used to identify ADHD children.

Estimates of interobserver reliability between the two observers were taken periodically. A total of 30% of the phases were compared on a trial-by-trial basis within each category, per phase. Trials were scored as being in agreement if both observers agreed on the occurrence or nonoccurrence of a response within each trial. Interobserver agreement was calculated by dividing the number of agreements by the number of agreements plus disagreements and multiplying this value by 100. Agreement indices ranged from 71% to 100% with a mean of 88.86% (SD = 10.69) for fidgeting. Agreement indices for intervals out of the seat ranged from 86% to 100% with a mean of 96.46 (SD = 4.84).

Rates of engagement with the two toys and holding of the music cord from Phase B also were derived from the observational system. Interobserver reliabilities for these categories were obtained the same way they were for rates of activity. Again, reliability was done on 30% of these data. For the table top toy, agreement indices ranged from 91% to 100% with a mean of 97.78% (SD = 3.27). Agreement indices for intervals of engagement with the spin toy ranged from 90% to 100% with a mean of 96.56% (SD = 4.39). Indices for rates of holding the music cord ranged from 89% to 100% with a mean of 96.56% (SD = 4.36).

Experimental Design

Both within-subject and between group comparisons were used to assess self-control responding and the collateral dependent measures. For the within-subject comparisons, a set of three phases, on each of two days constituted the experimental sequence, permitting the responding of each boy under A to be compared with his responding under B. The phases consisted of Phase A_1, without the music or toy options, Phase B with the music and toys, and a return to Phase A (A_2) to complete the sequence each day. The sequence was repeated as an A_1BA_2 A_1BA_2 design, on an individual basis, within each subject and across both groups. The interval between Day 1 and Day 2 varied between subjects, depending on their parents' schedule, with a mean average of 2 weeks between days for the ADHD and typical group. Various comparisons were made between the performances of children in the typical (control) and the ADHD (experimental) groups [the most common statistical technique was an ANOVA with one group factor (ADHD versus typical) and two within-subject factors (Days 1 & 2; Phases A_1, B A_2)--see Results Section for additional information.]

Procedure

Operation of Choice Apparatus

Figure 3 presents a diagram of the procedure and main dependent measure; a discrete-trial, chain procedure. In a chained schedule, the subject receives reinforcement after completing two or more schedules consecutively (Ferster & Skinner, 1957). In this experiment the subject pushed an illuminated button once (a Fixed Ratio 1 schedule) to start the initial link of the trial. At this time a siren sounded and the middle display of the stimulus projector illuminated a green light, to cue the

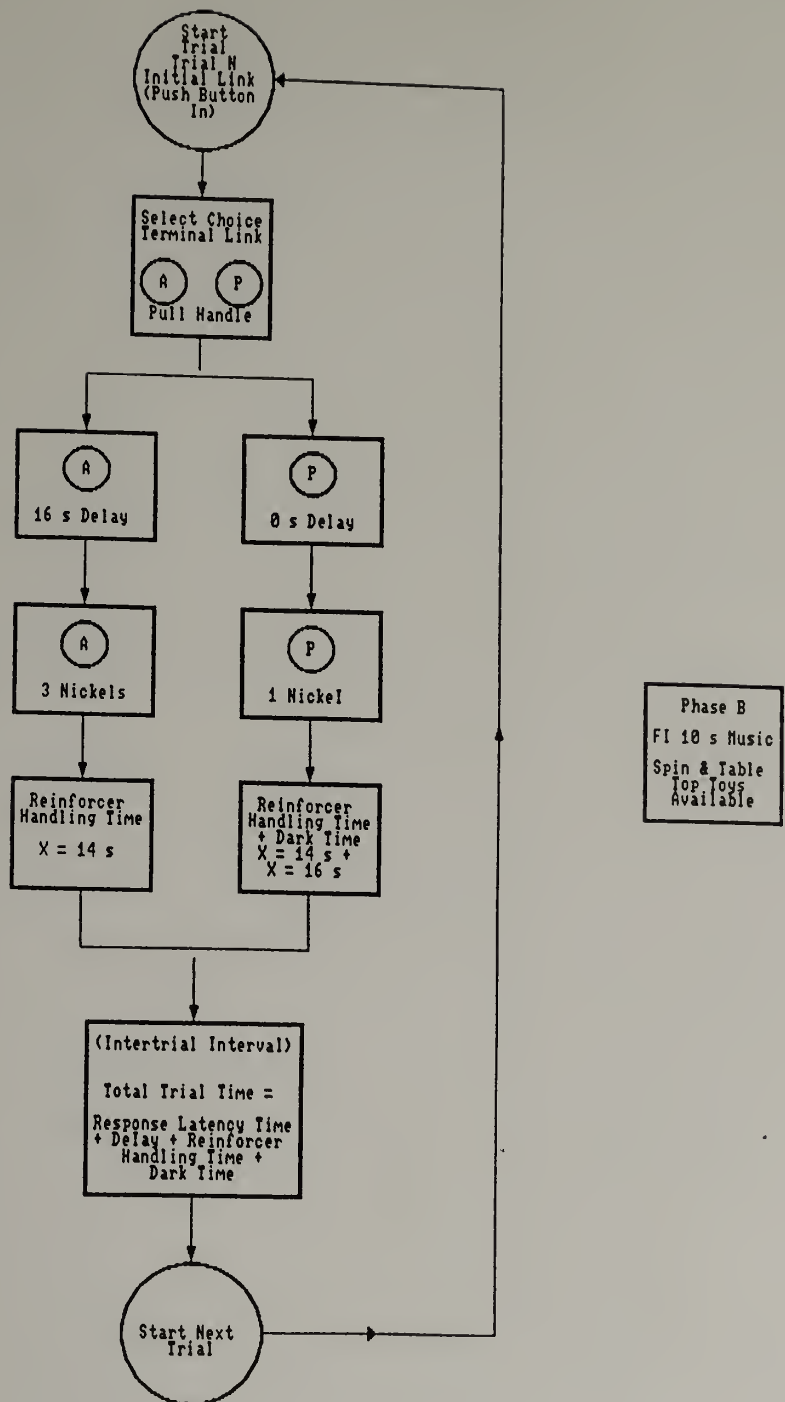

Fig. 3. Diagram of the choice procedure. A represents the amber light and is paired with the delivery of 3 nickels; P represents the purple light and is paired with the delivery of 1 nickel.

subject that the next trial could now begin. Immediately after the button was pushed, its green light was extinguished, the siren stopped and a purple and amber light on the left and right side of the stimulus projector was illuminated above each handle, to indicate the onset of the choice trial (terminal link). At this point, the subject chose the immediate (0 s) or delayed reinforcer(s) (16 s) by pulling out one of the handles. The purple and amber lights varied from side to side on the projector in a random fashion from one trial to the next (randomization was determined by the computer). (The subject could not have access to this choice/terminal link phase until the initial link button had been pressed.) If both handles were pulled, the first would be activated. If they both were pulled at exactly the same time, nothing would happen and the child had to choose again. After the appropriate delay, the nickels were dispensed--one for the purple light; three for the amber light. An advantage of this chain procedure was that it provided two measures of response time. The extra effort involved in performing the two operations also may have helped reduce random choices by the subject.

<u>Orientation of Subject and General Procedure</u>

The experimenter and child's parent accompanied each child to the testing room and explained that they were going to play a nickel game. Once in the room, the experimenter showed the apple bank to the child and demonstrated how it worked. Each subject then fed nickels to the bank until two were successfully "swallowed" by the bank's worm. Then the reinforcer tray with its six items was presented and the subject asked to rank order each from his least to most favorite. The experimenter proceeded by pricing items accordingly, at 10 to 50 nickels each. She assigned the highest price to the most favored, the next price to the second, and so on until all were assigned a value. The child was told how many nickels he would need for the each item. Next an actometer was placed on the wrist of the child's dominant hand and on the ankle diagonal to that hand. Before the first phase began on the first day, the experimenter told the child how the apparatus worked through modeling and the following instructions:

> When you pull these handles out nickels will come out of here (pointed to nickel dispenser). You need to put the nickels in the bank. You have to push this button in when you hear a siren come on. Then you'll be able to choose between 3 nickels after a while, or 1 nickel right away.

The experimenter then went to the adjacent room with the tray of rewards and activated the computer and video recorder. She then returned to the testing room to demonstrate the apparatus. (The apparatus always was locked when the child was to be left alone with it.)

At the beginning of each phase, four forced-choice trials were presented. These were used to acquaint the subject with the relation between the colors of the lights, the delay period, and the number of nickels dispensed. These forced-choice trials consisted of two random presentations with only one stimulus display projector illuminated and its corresponding handle operable at a time. The other light was not lit and its corresponding handle was nonfunctional during the forced choice trials. The rationale for including these forced-choices was that one could not contend that a subject had made a "choice".

When the experimenter returned to the room and activated the apparatus, she gave each subject the following instructions:

> Remember, when you hear this noise, see the green light on, (stimulus projector-center display), and this button light up, you are supposed to push this button in. Do it now. Right. (If the child pushed the button in, if the child did not, the experimenter modeled pushing it in.) Now, see this light? (One of the left or right stimulus display panels.) Pull the handle under this light.

If the light was purple, the nickel was immediately delivered and the experimenter asked the subject how many nickels were presented and if he had to wait before the delivery. To insure that the subject understood the schedule, the experimenter told the subject that one nickel had been dispensed right away. If the light was amber, the child was instructed to wait to see what would happen. After the dispenser delivered three nickels, the experimenter asked how many nickels had been dispensed and whether there had been a wait. Again, the experimenter verified his correct description or informed him about the wait and that three nickels had been dispensed. Then the experimenter explained that the colors would switch sides. She then continued with

> Now put your nickel(s) in the bank. (During the postreinforcer times, the experimenter pointed to the stimulus projector and said that the purple and amber colors would change from side to side.) Sometimes orange (amber) will be on this side and sometimes it will be on the other side. Sometimes purple will be on this side and sometimes on the other side. You have to pull the handle under the color you want. First we'll only have one color at a time, but soon you can choose between the orange and purple colors at the same time.

Throughout the four forced-choice trials the experimenter continued asking the subject to describe the reinforcer amount associated with each color and whether or not a delay was required (the subject was not asked about the specific length of the delay; simply whether or not a delay occurred after he pulled the handle and before he received a nickel). On the third forced-choice trial of the first phase the experimenter said the following:

> You will have one more time with just one color. After this you can choose between purple and orange. From now on you have to choose between purple and orange. Pull the handle under the one you want. Remember, the purple and orange change from side to side (as experimenter pointed to left and right projector displays). Do you have any questions?

Parents also were asked if they had questions at this point. None ever did. The experimenter then wound the apple bank and told the subject that she would come and check on him in a few minutes but that she needed to go into the next room and to do some work. At this point the parent also left and the experimenter explained that the parent would be in the waiting room.

The beginning of the remaining five phases was the same, except that the parent did not accompany the child and each child was only asked twice during the forced choice phase how many nickels would be delivered with purple and orange and whether or not a delay was required. Some of the rewards in the tray were changed before each phase to permit access to a variety and limit possible satiation effects. Typically if a child had been unable to earn enough nickels to buy the most highly-favored reward, the experimenter kept that reward in the tray as one of the six available stimuli.

While the subject was being tested, the experimenter watched from the adjacent observation room, entering the testing room an average of 1.5 times/session to wind the apple bank during postreinforcer times. (The experimenter also entered the testing room for Subject 14 when he turned the lights out and broke the bank. She instructed him that the lights had to remain on if he wanted to trade his nickels in for toys later.)

Before the B phase began, the experimenter played 20 s of four music tapes and had the child select one. The selected tape was placed in the apparatus and connected to permit operation through the computer. Using the following instructions, the experimenter then showed the subjects how to push the button to hear the music and demonstrated how to use the two spin toys. The subject also was instructed to try the two toys.

> See this red button? When you press it, the box plays music for a little while. You can use this throughout the game now. If you want to hear music, all you have to do is push this button in to start it. Everything else works the same as with the nickel game; you just have the music and toys to play with as well now.

The experimenter also told subjects that they did not have to place the nickels in the bank right away if they did not want to. (During piloting sessions it appeared that subjects seemed overwhelmed with trying to perform all of the concurrent tasks of the B phase.)

<u>Phase A_1</u>. The purpose of the A phase was to determine subjects' percentage of choices of the larger, delayed reinforcer over the smaller, immediate one during the 16 trials that followed the four forced-choice trials. This series of trials usually ran approximately 14 minutes each, depending upon how long it took the child to initiate the trial and choose a schedule.

<u>Phase B: Addition of Music and Toys</u>. During the B phase, the three other stimuli also were made available to the subject throughout: access to 10 s of music on a fixed interval schedule throughout the session contingent upon pressing the activating button, and the two spin toys.

Phase A_2. This phase was exactly the same as the first A phase: forced choice and choice trials without access to music and toys.

Intertrial Intervals. Within each session, the intertrial intervals (ITI, time between onset of successive trials) were determined by a computer program to insure that the overall rate of reinforcement and session length was held relatively constant for each subject, regardless of his choice behavior. Trials were made equivalent by adding a delay to the postreinforcer period following choices for the immediate reinforcer. This "dark time" delay was either 12 s or 20 s (M = 16 s) and determined by a preset random schedule that insured the two dark time delays were presented an equal number of times. The mean dark time (16 s) was equivalent to the prereinforcer delay for the delayed, larger reinforcer. Thus each trial was approximately the same length, with the subject's choice determining whether the 16 s delay was to be a prereinforcer delay (choice for 3 nickels) or a postreinforcer delay (1 nickel).

Any differences in the session lengths experienced among subjects, were due to latency to respond to the initial or terminal links. All trials also included a postreinforcer time which gave the subject time to retrieve the nickel(s) from the dispenser and deposit it (them) in the bank. This reinforcer "handling time" was an average of 14 s and followed the delivery of the nickel(s) and was not dependent upon choice. The handling time was 10 s or 18 s (_M_ = 14 s) and determined by a present random computer schedule that insured that each interval would be presented 8 times during the session. Variable dark time and handling times were used to increase discriminability of the prereinforcer delay associated with the two choices available, and decrease discriminability between the postreinforcer times. The schedules were variable to reduce any potential effect of the postreinforcer times on subsequent choice decisions by the subject. (Subjects 1 and 18, the first subjects in the study, had delay times of 30 s for the large reinforcers and consequently had 30 s postreinforcer dark times following choice for the immediate reinforcers. The handling times following reinforcer delivery was 10 s. These subjects did not have variable handling or dark time periods.)

Post-phase Assessments

At the end of each phase in the study, the experimenter entered the testing room and showed the subject the rating scale for enjoyment (see Figure 2). The subject was asked to point to a face on the scale that corresponded to how much he enjoyed the game (a lot, some, don't care or so-so, not much, not at all). Next, the subject was asked to hold down a button for the amount of time he thought he had to wait for each of the two quantities of reinforcers. The experimenter timed the duration of each button press on a hand-held stop watch, with the face not visible to the child.

Exchanging Nickels and Break Time

The experimenter unclamped the apple bank, counted the nickels in view of the subject, and told him how many nickels he had earned. She then reviewed the prices of each of the toys in the reward tray. The subject then exchanged the nickels and brought the purchased item to the waiting room where his parent was waiting to spend a 15 minute break. Following the break, the toy was given to the parent to be taken home at the end of the day.

Contingency-Specifying Accounts

After the last phase, on the last day, each subject was asked to describe the contingencies in effect during the experiment (i.e., how the game worked). The child also was asked to say how long he had to wait for each of the two choices and to provide additional information about the testing experience. More specifically, the subject was asked the following questions:

Which color did you like better?
Did you like getting 1 or 3 nickels better?
How long did you have to wait for 1 nickel (purple)?
How long did you have to wait for 3 nickels (orange)?
How many nickels did you usually get? (1 or 3)
Now that you've played this game and know what orange and purple do, what is the way to get the most nickels in this game?
Did you say or think anything while waiting for 3 nickels? Did you think about the toys?
Was it hard to wait for 3 nickels? Why?
Do you have a bank at home?

The subject's parent was then asked if the child had a bank at home and if he saved money in the bank and bought items with his savings.

<u>IQ testing</u>

As described earlier, eight of the subjects without recent IQ scores needed to be tested. At the end of the first day, the experimenter administered the vocabulary section of the IQ test to these subjects. At the end of the second day, she administered the quantitative and spatial abilities section of the test.

CHAPTER 4

RESULTS

Choice for Delayed, Larger Reinforcer Versus Immediate, Smaller Reinforcer

Figure 4 presents box plots with the median number of choices for the delayed, larger reinforcers over sessions for each group. Choice for the delayed reinforcers were considered a measure of self-control. A repeated measure with one group factor (ADHD versus typical subjects) and two within-subject factors (Day 1 versus Day 2 and Phases A_1, B, and A_2) analysis of variance (SYSTAT) was performed. Mean scores on choice during each day and phase, together with F-values, probability levels and significant trend tests are reported in Table 2. [1]Individual subject data are presented in Table 3. Typical subjects chose the delayed reinforcer more frequently overall with a group average of 13.80, in contrast to 9.10 delayed choices for the ADHD subjects. There was an overall significant group difference between the two samples $F(1,16) = 12.82$, $p<.01$, MSe = 45.45. Choice for the delayed reinforcer increased, or stayed the same, from Day 1 to Day 2 for the typical subjects, while choice for the delayed reinforcer decreased from Day 1 to Day 2 for the ADHD subjects. This Group x Day interaction was reliable $F(1,16) = 12.78$, $p<.01$, MSe = 10.41.

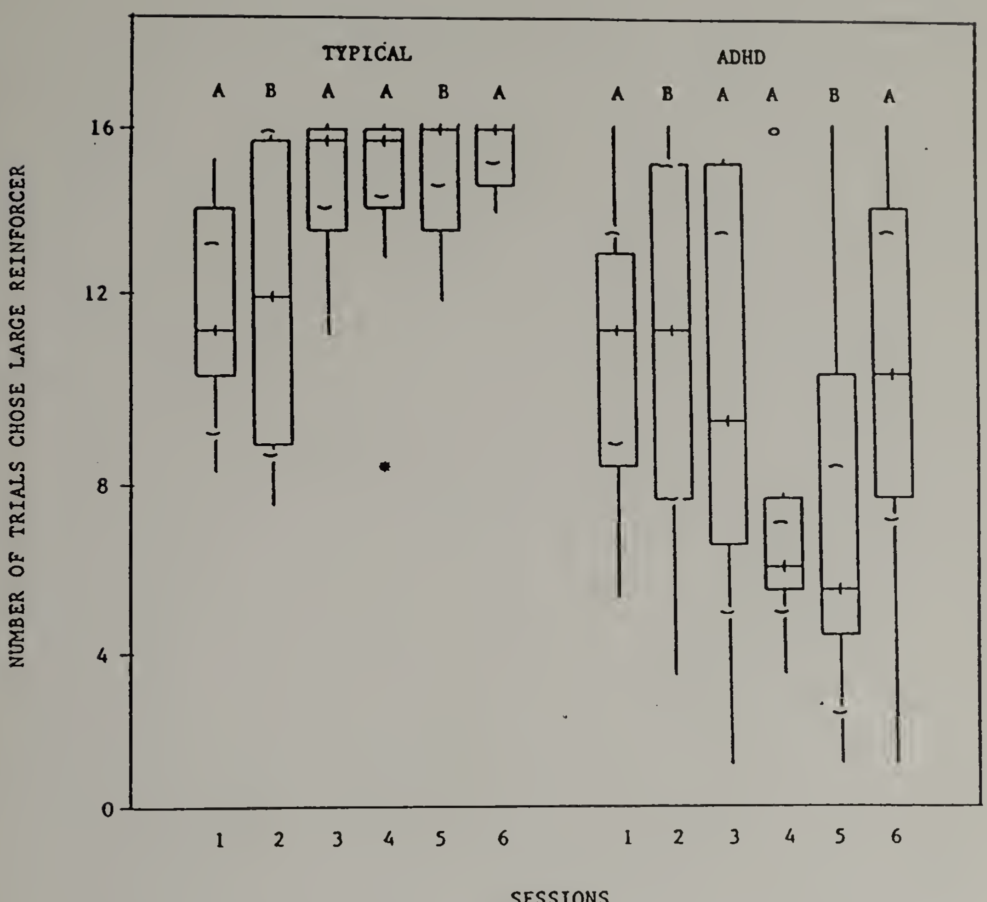

Fig. 4. The median number of trials during each phase the larger reinforcer was chosen out of 16 trials. The cross marks indicate the median; the end of each whisker represents the outermost score for the group; the parentheses indicate 95% confidence intervals; *represents a score that lies 1.5 interquartile distance from the median and 0 represents a score that lies 2 interquartile distance from the median.

Table 2

Comparison of Choice for Larger, Delayed Reinforcers

		Day 1			Day 2		
Group	Phase	A_1	B	A_2	A_1	B	A_2
Typical (N=8)	*M*	11.63	11.88	14.63	14.38	14.88	15.38
	SD	2.56	3.76	2.00	2.77	1.81	.92
ADHD (N=10)	*M*	10.80	10.60	9.40	7.40	6.70	9.70
	SD	3.52	4.45	5.02	4.70	4.47	4.67

	df	MSe	F	P	Trend Tests
Group	(1,16)	45.45	12.82	0.002	
Day	(1,16)	10.41	0.01	0.916	
Day X Group	(1,16)	10.41	12.78	0.003	
Phase	(2,32)	6.10	3.32	0.049	L, p=.064
Phase X Group	(2,32)	6.10	0.72	0.496	
Phase X Day	(2,32)	7.06	0.45	0.639	
Phase X Day X Group	(2,32)	7.06	4.23	0.023	L, p=.041

Note: L = Linear Trend

Table 3

Number of Trials Subject

Chose Larger, Delayed Reinforcer

		Day 1			Day 2		
Subject	Phase	A_1	B	A_2	A_1	B	A_2
Typical							
1		15	16	16	16	16	16
2		13	14	15	15	15	14
3		8	7	16	16	16	14
4		10	15	15	13	16	15
5		10	10	11	8	12	16
6		15	16	16	16	16	16
7		10	8	12	16	12	16
8		12	9	16	15	16	16
ADHD							
9		5	3	1	5	5	1
10		11	15	15	16	10	16
11		6	13	13	3	4	10
12		13	10	4	5	1	11
13		14	12	10	7	9	8
14		11	7	8	4	4	*5
15		11	16	15	7	3	10
16		13	15	15	16	16	15
17		8	10	6	6	10	14
18		16	5	7	5	5	7

Note. There were 16 choice trials per phase. *Estimated.

Contrasts were performed to assess the effect of phases and days on the group's choice responding. In order to assess the effect of the music and toys on choice, contrasts were performed on choice data from the A_1 and B phases. Since responding in the A_2 phases may have been influenced by factors in the B phases, the contrast excluded the A_2 phase from the analyses. The first contrast showed that the B phase did not alter subjects' responding from the first A phase for both groups, t (32) = .03, p>.1. Therefore, the hypothesis that music and toys would increase choice for the large reinforcer in a reliable way was not confirmed. The next contrast was done to determine if responding in phase A_2 was different than responding in the other two phases. This contrast was performed because the experimenter suspected that choice responding in some children was influenced by the knowledge that the A_2 phase was the last opportunity to earn a highly favored, and as yet, unearned toy. A comparison of the performances during the A_2 phases with the combined average performances of the A_1 and B phases showed that choice for the larger, delayed reinforcer was significantly greater during the A_2 phases than the average of the other phases $t(32) = 2.47$, $p<.05$.

Each group was affected differentially by day and phase. The typical subjects chose the delayed reinforcers to an increasing degree on five out of six consecutive phases, and from Day 1 to Day 2, with a mean of 11.63, 11.88, 14.63, 14.38, 14.88, and 15.38 for phases one through six respectively. In contrast, the ADHD subjects chose the delayed reinforcer to a decreasing degree on five out of six phases and from Day 1 to Day 2, with a mean of 10.80, 10.60, 9.40, 7.40, 6.70, and 9.70 for phases one through six. The typical subjects chose the delayed reinforcer more frequently during A_2 than A_1 and B on both days. The ADHD subjects selected the delayed reinforcer during A_2 more frequently on Day 2, but still less frequently than on A_1 and B of Day 1. An analyses assessing the three way-interaction between, phase, day, and group confirmed that choice for the delayed reinforcer was a function of the group phase and day $F(2,32)=4.23$, $p<.05$, MSe = 7.06.

To assess whether performance during phase A_2 was responsible for the phase differences in the 3 way-interaction, A_1 and B were averaged together and compared to A_2. This contrast showed that groups responded differentially during the A_2 phase from A_1 and B depending on the group and day $t(32) = 2.78$, $p<.01$. ADHD group responding during the A_2 phase of Day 2 may have increased because it was the last opportunity to earn toys.

<u>Response Time to Initial Link</u>

[2]These analyses evaluated the latency to initiate trials once the apparatus signaled that a new trial could begin. The average group mean over phases, to start a

trial for the typical group was 2.85 s (*SD* = .76), while the average for the ADHD group was higher at 5.26 s (*SD* = 3.36) and more variable. An ANOVA consisting of repeated measures with one group and two within-subject factors did not show a significant group difference $p > .1$ or a main effect for days $p > .05$. The addition of the music and toys affected response time in both groups with latencies of 3.51 s for A phases and 5.13 s for B phases when time was collapsed over groups. A main effect for phases approached significance with latencies during B phases longer than A phases F (2,32) = 3.149, $p < .06$ (p = 0.056) MSe = 13.257. For both groups the A_1 phase on Day 1 was the shortest latency compared to the other five sessions. Latencies during the A_2 phase on Day 2 also were longer than the A_2 phase on Day 1. Subjects' initial latency increased in a significantly linear fashion F (1,16) = 4.868, $p < .05$, MSe = 3.011. To determine whether there was a relationship between rates of activity and latencies, a Pearson product-moment correlation was performed. The test demonstrated a relationship between actometer scores and initial link response times (r = .73, $p < .01$) suggesting that children with higher rates of activity had longer response latencies. This is not surprising since those subjects who were more active often were farther away from the apparatus and consequently had more distance to travel to reach the machine to start the next trial.

Response Time to Terminal Link

Both groups took approximately the same time to choose between reinforcement schedules, with a mean in seconds of 2.42 for the typical group and a mean of 2.96 s for the ADHD group. The slight difference between groups in their latencies was not significant $p > .1$. Latency between phases were significant, $F(2,32) = 4.985$, $p < .05$, MSe = 2.22, with subjects taking a longer time to choose during the B phase ($M = 2.37$ s) when the additional sources of reinforcement were available than the A phase ($M = 3.31$ s). A correlation between choice and latency time was done to determine if subjects who chose a particular schedule were faster in executing their choice. A Pearson product-moment correlation showed a significantly negative relationship between reinforcer choice and latency time with shorter latencies correlated with greater choice for the larger, delayed reinforcer $r = .51$, $p < .05$. Since latency is a measure of response strength, this correlation suggests that the amber light (associated with delayed reinforcers) had gained stronger stimulus control over responding. This correlation and other data on rates of activity show that there may be fewer competing responses contributing to latency time (e.g., evaluating both schedules at once or fiddling with other objects in the room could lead to longer response times).

A correlation between initial and choice latencies was done to assess whether both latencies may have been affected in a similar way by environmental conditions. A Pearson product-moment correlation showed that there was a significant relationship between the initial link response times and the choice response times ($\underline{r}$ = .60, $\underline{p}$<.01). This suggests that both latency times were influenced by common factors.

Rates of Responding on Nonfunctional Manipulanda

Response rates per session were obtained by dividing the frequency of responses per phase by the total number of minutes during a choice-trial session. This category is composed of the following two response types: 1) terminal link responses, which were pulls on the same handle the child used to select a schedule, during the pre- and postreinforcer delay time; 2) other responses, which were pulls on the other handle or the push button made after the choice had been selected, or any pull on the handle at the time when the trial was first available after the siren sounded and the subject should have been pushing the button in to start the next trial. These data were analyzed in two ways, by combining terminal link and other responses and using an ANOVA with a one group factor and two within-subject factors (Day, Phase), and by separating out the two types of responses and using response type as a within-subject factor, with one group factor and three within subject factors (Day, Phase, Response Type). Figure 5 presents the combined means on response rates per group and session, while Table 4 shows the means and standard deviations in tabular form. When the two types of responses were combined, the ADHD group was found to make more nonfunctional responses ($\underline{X}$ = 1.69) than the typical group ($\underline{X}$ = .83). However, the ANOVA with the two within-subject factors showed no main effect for groups on the combined responses $\underline{F}$ (1,16) = 3.19, $\underline{p}$>.05, MSe = 7.468.

There was evidence that the availability of music and toys was associated with decreased rates of responding on the combined terminal and other responses during the B phases. The mean rates of responding during the A phases ($\underline{X}$ = 1.42) were higher than those during the B phases ($\underline{X}$ = .95). The rise and fall of responding between the A and B phases approached significance with a quadratic trend between phases $\underline{F}$(1,26) = 4.46, $\underline{p}$ <.06 ($\underline{p}$=.051), MSe = .978.

The data on use of the nonfunctional manipulanda were then analyzed with type of response as a within subject variable. Figure 5 shows the pronounced difference between the groups when data from Day 1 of the ADHD children are contrasted with data from the typical children. The average rate of responding collapsed over response type for typical subjects was .91, on Day 1 and .84 on Day 2. The average rate for the ADHD subjects

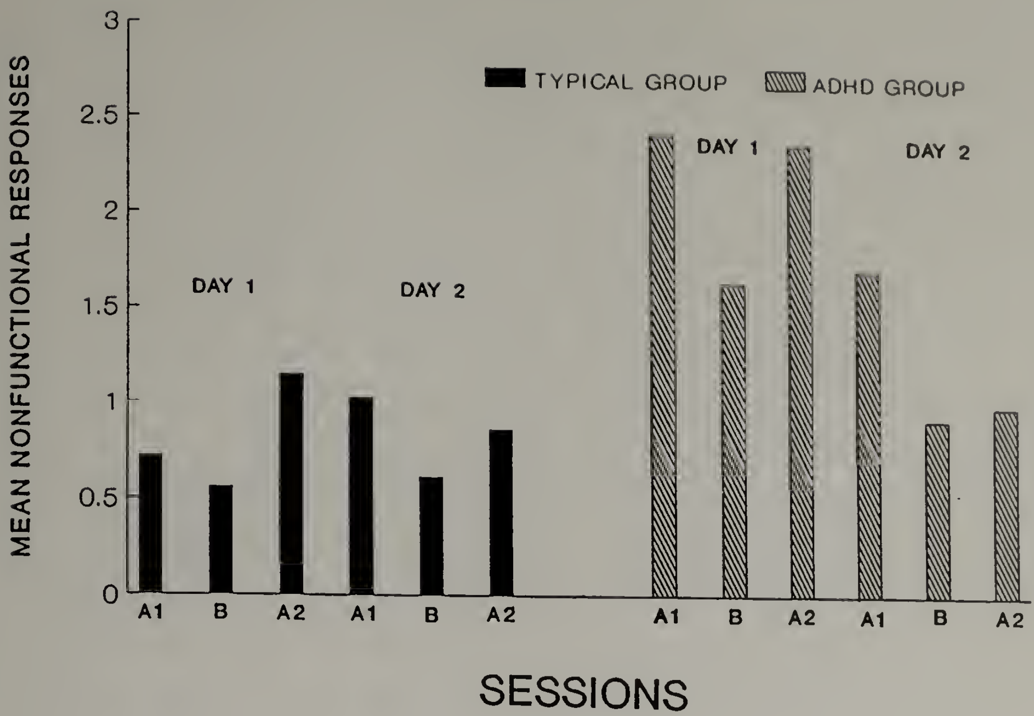

Fig. 5. The group mean rate of combined terminal link and other responses per session.

Table 4

Means for Combined Terminal and Other Responses on Nonfunctional Manipulanda

		Day 1			Day 2		
Group	Phase	A_1	B	A_2	A_1	B	A_2
Typical (N=8)	M	0.72	0.56	1.15	1.03	0.62	0.87
	SD	1.43	1.08	1.95	1.51	1.23	1.03
ADHD (N=10)	M	2.43	1.65	2.38	1.72	0.93	1.00
	SD	3.08	2.15	2.93	1.23	0.90	0.99

was 2.15 on Day 1, and 1.22 on Day 2. A marginally significant Day x Group interaction emerged with typical subjects exhibiting similar rates of responding between Day 1 and Day 2, while ADHD subjects decreased their rates of responding from Day 1 to Day 2 $\underline{F}(1,16) = 4.019$, $\underline{p}<.07$ ($\underline{p}=.062$), MSe = 14.48. These data demonstrate the effect of the additional sources of reinforcement on the dispersion of responses within the experimental context, showing that music and toys reduced the rate of nonfunctional responses across groups.

<u>Actometer Ratings</u>

[3]The actometer data also may explain the decrease in nonfunctional responding by the ADHD group from Day 1 to Day 2. If the behavior of ADHD subjects were controlled by stimuli other than those provided by the choice task, one might expect to see higher rates of activity. Indeed, Figure 6 and the means and standard deviations in Table 5, show that the actometer-measured rates of activity increased for the ADHD subjects as their rates of responding on the terminal link and other responses decreased. The typical subjects had increased rates of activity from Day 1 to Day 2 with a mean of 29 and 36 respectively, but the ADHD subjects had a much higher rate of activity, particularly on Day 2 when the responses to the nonfunctional apparatus declined, with a mean of 39 on Day 1 and a mean of 73 on Day 2. The repeated measures by

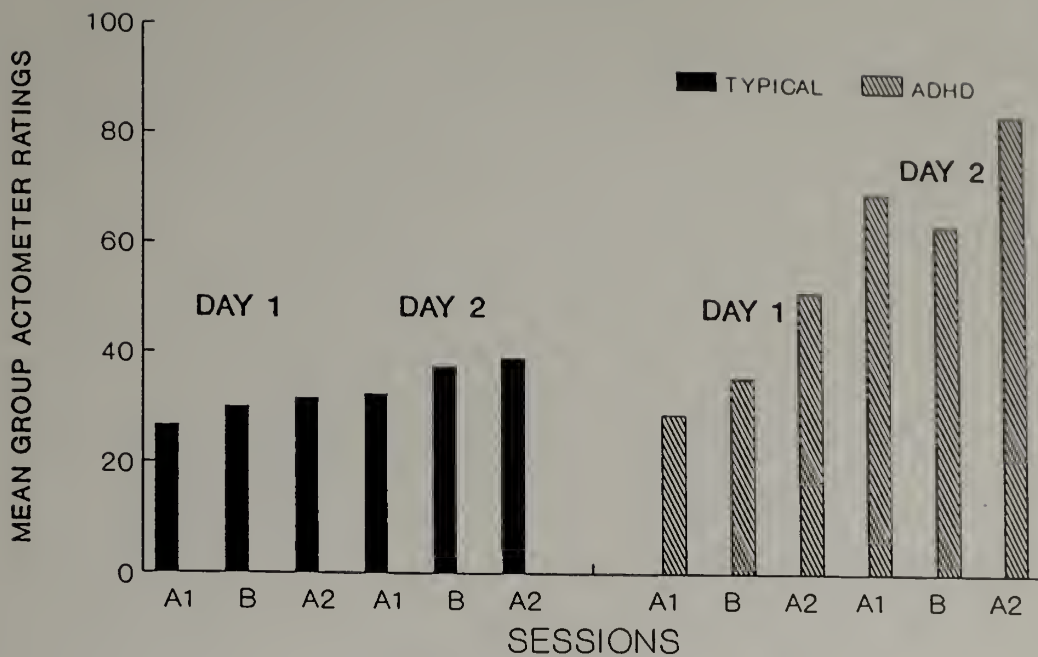

Fig. 6. The group mean rate of motion as recorded by actometers for each session.

Table 5

Mean Actometer Scores by Group

		Day 1			Day 2		
Group	Phase	A_1	B	A_2	A_1	B	A_2
Typical (N=8)							
	M	26.72	30.02	31.62	32.45	37.59	39.02
	SD	15.59	14.21	12.91	11.56	11.91	15.60
ADHD (N=10)							
	M	29.00	35.77	51.71	70.15	64.38	84.96
	SD	19.58	13.98	19.89	46.07	43.87	48.13

group ANOVA showed a significant Group x Day interaction $F(1,16) = 5.103$, $p < .05$, $MSe = 983.15$. The availability of music and toys may have served to lower rates of activity for the ADHD group, particularly on Day 2 when their rates of activity were highest. The actometer ratings were lowest during Phase B for the ADHD group on the second day.

The overall actometer rates also differed reliably with a typical group mean of 33 and an ADHD mean of 56. These between group differences were significant $F(1,16) = 5.696$, $p<.05$, $MSe = 2495.96$. There was more stability in the data from the typical group over phases and between days, in comparison to the data from the ADHD group. The differences between days when collapsed across groups was significant with a mean of 34 on Day 1 and a mean of 53 on Day 2 $F(1,16) = 11.53$, $p<.01$, $MSe = 983.15$. Rates of increased over phases with rates of activity highest during the A_2 phases for both groups with an overall mean of 39.58 for Phase A_1, 41.95 for B, 51.83 for A_2. A main effect for phases was significant with $F(2,32) = 3.92$, $p<.05$, $MSe = 382.588$.

A test was performed to determine if preference for the delayed reinforcer was related to the actometer ratings, another diagnostic tool used in assessing ADHD. A significantly negative Pearson product-moment correlation between choice and actometer ratings ($r = -.60$, $p<.01$) suggests that this task's measure of choice for the delayed reinforcer is related to rates of activity, with lower rates associated with choice for delayed, larger reinforcers. Thus rates of activity covaried with choice for the delayed reinforcer. The experimenter also was interested in whether rates of activity were related to children's estimation of time delay for the large reinforcer. A Pearson product-moment correlation showed that children who had the higher actometer scores also were less accurate in verbally describing the length of the delay for the larger, delayed reinforcer ($\underline{r}$ = .67, $\underline{p}$<.01).

Measures of Activity Derived from the Videotape

Videotape measures of activity were consistent with other measures of activity and showed that the ADHD group was more active and more frequently out of their seats than the the typical group. Table 6 presents means, standard deviations, and ANOVAs for the rates of intervals in which subjects left their chairs during the experimental testing. The amount of time subjects' spent out of their seats corresponded to the actometer rates of locomotion and showed similar patterns between groups and days with more exposure to the task corresponding to higher rates of time spent out of the seat for the ADHD group. The overall group rate for the ADHD group was 43.48 intervals out of seat, while it was only 12.80 intervals for the typical group. There was an increase of

Table 6

Comparison of Rates of Time Subjects Were out of Their Chairs

		Day 1			Day 2		
Group	Phase	A_1	B	A_2	A_1	B	A_2
Typical (N=8)	*M*	4.13	18.25	11.88	8.25	22.63	11.63
	SD	4.97	12.92	12.02	8.73	23.74	9.38
ADHD (N=10)	M	19.90	43.40	35.70	44.90	63.10	53.90
	SD	28.66	31.91	28.86	35.36	35.17	37.72

	df	MSe	F	P	Trend Tests
Group	(1,16)	2751.96	9.13	0.008	
Day	(1,16)	578.63	6.48	0.022	
Day X Group	(1,16)	578.63	3.82	0.068	
Phase	(2,32)	277.73	9.86	0.000	L, p=.034; Q, p=.034
Phase X Group	(2,32)	277.73	0.48	0.622	
Phase X Day	(2,32)	141.31	0.49	0.616	
Phase X Day X Group	(2,32)	141.31	0.12	0.890	

Note: L = Linear Trend; Q = Quadratic Trend

20.97 intervals between Day 1 and Day 2 for the ADHD children, while there was only an increase of 2.75 intervals between days for the typical children. Children also were significantly more likely to leave their chair during the music and toy phase. This is not surprising since it was easier to reach all the concurrent tasks (i.e., apparatus, bank, toys, music cord) while standing rather than sitting. Higher rates of standing in some subjects was due to a preference for standing up and dancing while listening to the music during the B phases.

Another videotape measure of more fine motor activity, fidgeting, showed higher rates of fidgeting for the typical children ($\underline{X}$ = 34.77, $\underline{SD}$ = 19.80) than the ADHD children ($\underline{X}$ = 25.27, $\underline{SD}$ = 13.81), however, these group differences were not significant $\underline{p}>.05$. Fine motor movement unrelated to task activity decreased during the B phases; the overall session means for A phases was 32.99 and for B phases 24.08. The difference between the A and B phases collapsed across groups was significant $\underline{F}(2,32) = 5.80$, $\underline{p}<.01$, MSe = 248.670 and appeared in curvilinear fashion, decreasing when additional activities were available in the B phases $\underline{F}(1,16) = 9.22$, $\underline{p}<.01$, MSe = 204.40. Along with the actometer data and rates of responding on nonfunctional manipulanda, these data provide further evidence that various forms of activity decrease when other forms (music and toys) are provided.

Rates of Responding for Toys and Music during Phase B

Although many of the previous data revealed differences in rates of activity between the groups, few differences were found in rates of engagement with the additional activities when they were provided during the B phases. The overall session means on rates of responding for the music per trial for the ADHD group was 11.78 and for the typical group 12.15. No statistical differences were found between groups or days on the rates of response to activate the tape-recorded music $p > .1$. The videotaped measure of frequency in which the subjects held the button that activated the music, also did not differ between groups or days, with an overall mean for the ADHD group of 69.5 intervals (SD = 29.53) and for the typical group 83 (SD = 22.28) $p > .1$. Appendix C presents cumulative response rate records for each subject. These graphs demonstrate that the music did function as a reinforcer since responding was maintained at fairly steady rates across subjects.

Before we can test the hypothesis that additional reinforcers may alter self-control responding, we must establish that the added stimuli function as reinforcers; the data on response rates do establish that the music was a reinforcer. In general, the slope and number of changes in direction in the response rate over time were similar between the groups. However, there was evidence of a decelerating response curve in seven of the sessions for the ADHD group, and in only three of the sessions for the typical groups. A closer inspection shows a marginal difference emerged in response rates between groups on the last 3 trials of the session when 33% of the ADHD group, in contrast to 13% of the typical group, stopped responding on the music button before the session ended. The rates of responding on the toys available during the B phases was quite similar between groups and days. Both groups were engaged with the table top toy during an average of 8 (ADHD <u>SD</u> = 10.68; typical <u>SD</u> = 13.46) intervals of the B phase. The typical group was engaged with the spin toy during an average of 27 (<u>SD</u> = 28.71) intervals, while the ADHD group used it an average of 22 (<u>SD</u> = 23.11) intervals during the B phase. The differences between the groups was not reliable <u>p</u>>.1.

<u>Estimations for Delay Time</u>
<u>for Immediate and Delayed Reinforcers</u>

Difference scores between the true delay values (0 s, 16 s, and 30 s for two subjects) were tested between groups. There was a great deal of between-subject variability in the verbally estimated values of the short delay, with a mean difference score of 15.25 for the typical group and a standard deviation of 27.04, and a mean of 89.20 and a standard deviation of 120.67 for the ADHD group. There was even more variability in the verbal estimation of the long delay, with greater variability in estimations by the

ADHD group, with a mean for the typical group of 223.88 and a standard deviation of 402.82 and a mean for the ADHD group of 720 and a standard deviation of 1135.91. Between group t-tests showed no reliable differences between group verbal estimates for the short delay ($p>.05$) or for the long delay $p>.1$. An analysis revealed that both groups were more accurate in verbally estimating the short delay than the long delay, with an average difference score of 56.33 for the short delay and 522.83 for the long delay with differences between estimates for long versus short delays approaching significance $F = 4.38$, $p<.06$ ($p=.053$), MSe = 394168.67). The nonverbal estimations of the delay to the large reinforcer also were quite variable within each group (typical group SD = 5.84; ADHD group SD = 5.53), but the typical subjects were slightly better at estimating the large delay ($\underline{X}$ = 8.71 s) than the ADHD subjects ($\underline{X}$ = 11.30 s). However this difference did not prove reliable $p>.05$. A correlation was performed to test the correspondence between the verbal and nonverbal estimation abilities of the subjects. A Pearson product-moment test revealed that there was no significant relationship between subjects' verbal and nonverbal estimations of the delays. This suggests that accuracy in time estimation may depend upon the procedure used to gather the data.

Ratings of Task Enjoyment

Subjects' ratings of a five-point scale (1 signifying most enjoyment, 5 the least) showed few differences between the typical group ($\underline{X}$ = 1.19) and the ADHD group ($\underline{X}$ = 1.53) $\underline{p}>.1$. A main effect for sessions was more reliable with a mean of 1.21 on Day 1 and 1.51 on Day 2, which approached significance $\underline{p}<.1$ ($\underline{p}$ = .051). There were no reliable differences between groups or phases $\underline{p}>.1$. These data suggest that both groups verbally expressed the same amount of pleasure with the task, although their choice for the delayed reinforcers was significantly different.

Contingency Descriptions and Task Related Verbal Behavior

Approximately 90% of both groups were able to accurately specify the contingencies in effect during the task when questioned after the experiment. Only one subject from each group failed to say that either orange, or 3 nickels, must be chosen to earn the greatest number of nickels in the task. Verbal preference for one or three nickels varied somewhat with 7 out of 10 from the ADHD group preferring three and 8 out of 8 of the typical group preferring three nickels. Those differences were not reliable however, on a between group Chi-square test $\underline{p}>.05$. Those children who preferred one nickel said they did not like to wait for the three associated with the long delay.

At times between the sessions, subjects would spontaneously comment to the experimenter on their planned or prior choice performance. The correspondence between what the children said they would do, or did do (in terms of schedules chosen) varied between and within subjects. After the testing on the final day, the experimenter asked the subjects to describe their performance in the test (How many nickels did you usually choose?) Overall, the subjects were accurate, with 8 out of 10 from the ADHD group and 8 out of 8 from the typical group capable of correctly describing their performance. The rate of accuracy between the groups did not differ on a X^2 test $\underline{p}>.1$.

The subjects seemed too young to understand or answer the question about whether they did anything or thought about anything during the delays. When they first answered this question 8 out of 8 of the typical children said, "no", and 6 out of 10 of the ADHD children said "no", as to whether they had done or thought about anything. A Chi-square test showed that these group differences were reliable $\underline{X}^2$ (1, $\underline{N}$ = 18) = 4.12, $\underline{p}<.05$. When the experimenter then asked if they had thought about the toys they could earn during the delays, 50% of each group said that they had. One typical child and one ADHD child said they were counting during the delays, but the experimenter observed at least two other typical children who also were counting during the delays. An ADHD child who usually chose one nickel said that he was calling himself "stupid" during the task because he could not figure the task out and how to earn the toys he wanted.

More ADHD children (7 out of 10) said it was difficult to wait during the delays for the nickels than typical children (3 out of 8). The group differences were not proven reliable on a Chi-square test $\underline{X}^2$ = $\underline{p}$>.1. This verbal behavior did not necessarily correlate with their choice responses and whether they chose to delay or not.

The experimenter also asked parents and children about their previous experience with saving money and using a bank at home. There were no differences between the groups, with 6 out of 8 of the typical children and 7 out of 10 of the ADHD children having some experience with a bank and saving money. Therefore, it is unlikely that previous experience with saving and waiting to spend money at home influenced responding during the experiment.

Summary of Results

Data from this study show that ADHD subjects are less likely to choose delayed, larger reinforcers than their counterparts in a choice task and that choice for the delayed reinforcers decreases in that group over time. During the A_2 phase of Day 2, the ADHD children chose the delayed reinforcer more than any other session that day.

Most measures of activity showed group differences as well, with the ADHD group particularly more active on the second day. The rates of actometer motion were significantly related to rates of impulsivity. The lower rates of nonfunctional responding on the apparatus on Day 2 for the ADHD group, combined with their higher rates of locomotion on the actometers for Day 2, suggest that they spent less time near the apparatus and found the task less reinforcing, or that they found other activities or stimuli in the room more reinforcing.

The addition of the music and toys during Phase B did not alter self-control in either group, but did result in somewhat lower rates of activity on the actometers, nonfunctional manipulanda, and fidgeting. The groups did not differ in their overall rates of responding for the additional reinforcers, but the ADHD subjects did make fewer responses to obtain music toward the end of their sessions.

Notes

[1]One ADHD subject (Subject 14) refused to participate in the last phase of the second day. The missing scores for choice, delay estimation, and ratings of enjoyment were estimated using a formula based on the group's overall scores, the group's scores from that session, and the individual's other 5 scores.

The first ADHD (Subject 18) and typical subject (Subject 1) were tested with 30 s delays for the long delay correlated with the larger reinforcer. There do not appear to be any differences between these subjects and their respective groups in choice for the larger reinforcer. Due to experimenter error, Subject 1 was tested on a 16 s delay on A_1 of Day 2. The subject was then tested with three more sessions B, A_2, and A_3 with a 30 s delay. During all phases on Day 2 and the last two phases of Day 1, this subject chose the delayed reinforcer 100% of the time. Time estimation scores for A_1 were based on estimations from the value of 16 s, but time estimations for Phase B of the subject were not used. These scores were instead estimated by the experimenter based on the accuracy of the subject's prior time estimations and scores from the typical group. (This subject clearly counted the length of the delay of the interval during A_1 on Day 2 and gave the same value after exposure to the B phase.)

[2]Originally, initial and terminal link data from A_1 on Day 2 from one ADHD subject were lost due to computer error. These data were later retrieved through a stopwatch scoring of a videotape of the Phase. Two observers watched the videotape and each scored the initial link and choice latency times of the 16 choice trials. The observers' scores for each response were averaged together for each trial and resulted in 16 separate scores for the initial latency data and 16 scores for the choice latency data.

[3]Several missing ankle actometer data were calculated through correlational procedures based on data from the subject's group and the available wrist actometer scores for each phase. Ankle scores for one ADHD and two typical subjects for all three phases on Day 2 needed to be estimated and one ankle datum for an ADHD subject who tampered with the actometer during Phase B of Day 2.

CHAPTER 5

DISCUSSION

Review of Results

The results indicated that ADHD children tended to choose delayed larger reinforcers less frequently than typical children in a discrete-trial, self-control task. Adding toys and music to the choice procedure did not reliably increase choice for the delayed, larger reinforcer in either group. With time, the differences in choice between the two groups became more pronounced as typical subjects consistently chose the larger reinforcer, and the ADHD subjects chose it increasingly less frequently. The only increase in self-control responding with the ADHD subjects occurred on the last phase of A_2. There was one exception in the ADHD group, a subject who almost always chose the delayed reinforcer. This subject had a fairly high IQ (122) and was reported to be at least 2 grade levels above his class in every scholastic area, but it is doubtful that IQ was solely responsible for his self-control since other subjects with high IQs in his group showed much more impulsivity. The experimenter does not know why his data were so different from others in the ADHD group.

Two possibilities may explain the ADHD boys' decreasing selection of the large delayed reinforcers: first they may have discriminated that this was their last opportunity to earn a reward they had wanted earlier but had not had enough money to earn. As the phase began, many asked the experimenter if the phase was the last one and some emphatically stated that they were going to earn a specific toy during that phase. Second, some of the ADHD children learned to engage in alternative reinforcing activities such as twirling or scooting their chairs by the last A_2 phase, which decreased the aversiveness of waiting for the delayed reinforcer. Some subjects were engaged in activities such as spinning a chair or "hiding out" under a table, for several seconds and would return to the apparatus at the time necessary to start the trial, choose a schedule, and then return to their activity.

Latency to Respond

Groups did not differ in the time it took them to start the initial or terminal links, but response time, a measure of response strength, was shorter for choices of the delayed schedule across the groups. Perhaps subjects who were physically closer to the apparatus, also were less likely to be engaged in competing responses, and their choice was more effectively reinforced by the nickels. Subjects who were across the room and engaged in twirling their chair would have had to leave the chair to initiate the trial may have found the nickels less reinforcing.

Maximizing Principle and

Relative Availability of Reinforcement

The choice behavior of the typical subjects in the study can be characterized as conforming to maximization models, in which "an organism with several responses available will emit the one with the maximum probability of reinforcement" (p. 183, Catania, 1984). In this model subjects distribute their responding to earn the maximum amount of reinforcement available over the entire session. The ADHD subjects' responding began by conforming to the maximization model, but shifted toward indifference between the two alternatives (1 or 3 nickels) as exposure to the task increased.

The ADHD subjects' responding seemed to have been more affected by r_e, the unknown aggregate of reinforcement received for behavior other than the nickels (e.g., chair twirling, manipulating the apple bank and the worm inside). As McDowell (1988) suggested, these alternative reinforcers can alter the effectiveness of a reinforcer that the experimenter is providing (i.e., the nickels). It is possible that because the ADHD subjects were more likely to engage in other responses that produced reinforcers, than typical subjects, they decreased their rates of choosing the larger number of nickels after a delay. However, the optimal maximization strategy would have been to select the delayed, larger reinforcer while engaging in the other (r_e) activities available. They only did this during the A_2 phase on the last day. (Several other descriptions and hypotheses concerning the group differences will be presented later in the Discussion Section).

Developmental and Species Differences

The typical children in this study responded similarly to the adults in the Logue et al. (1987) study, in that responding was more a function of reward size than delay. Due to procedural differences, only limited comparisons can be from these data to those from the Sonuga-Barke et al. (1989a; 1989b) studies in which 6 and 9 year old children preferred larger reinforcers, as did the typical children in this study.

Data from the typical children, however, are not consistent with findings from investigations with pigeons, younger children, younger impulsive children (Logue & Mazur, 1981; Logue, Rodriguez, Pena-Correal, & Mauro, 1984; Mazur & Logue, 1978; Schweitzer & Sulzer-Azaroff, 1989). In all of those studies, subjects' behavior appeared to be influenced more by delay than the amount of reinforcers with subjects preferring the immediate, small rewards, even when delays for the larger reinforcers were as short as 10 s with children (Schweitzer & Sulzer-Azaroff, 1989). Sonuga-Barke et al. (1989a) also found that half of his 4 year old subjects chose the immediate reward, with delay influencing choice. In the present study, the ADHD subjects' responding lay somewhere between the absolute self-control of the adults (Logue et al., 1987) and the impulsivity of pigeons and younger human subjects (e.g., Mazur & Logue, 1978; Schweitzer & Sulzer-Azaroff, 1989). It is doubtful that there was a decrement in choice from the larger reinforcer to the smaller one in the previous research involving pigeons and young children, as there was with the the present ADHD subjects. Presumably, the pigeons and young children began by choosing the immediate small reward and maintained this preference (unless an intervention was used). The overall choice responding of ADHD subjects also was consistent with the Rapport et al. (1986) findings that over longer delays, hyperactive subjects preferred more immediate rewards.

The differences in choice between the ADHD and typical group are suggestive of developmental differences. The Sonuga-Barke et al. (1989a, 1989b) and Golden et al. (1977) research showed that younger children are more impulsive, with responding a function of delay rather than amount of reward. The data from this study offer more evidence that ADHD children respond in an immature or developmentally delayed fashion.

Sonuga-Barke et al. (1989a) and Logue et al. (1987) hypothesized that developmental and species differences could be due to differences in verbal ability, with subjects who have a more complex verbal repertoire (including the ability to monitor delay durations) more likely to choose the more profitable alternative. Verbal differences may be particularly relevant to cases in which preference for a particular schedule is more profitable over sessions, rather than just on a trial by trial basis (e.g., Sonuga-Barke et al., 1989b). Subjects may have to be sophisticated enough to estimate pre- and postreinforcer delays while roughly calculating the amount of reward per the time required to earn them (rate).

The task in this study was less complex in that choice for the larger reward always resulted in more earnings. Post session questionnaires revealed that 90% of both groups could verbally describe that contingency and that all the boys learned that choice for the "orange" led to 3 nickels, while purple led to only 1 nickel. Therefore, it is unlikely that group differences were due to the ability to comprehend which alternative was the most profitable. (Furthermore, subjects in both groups had equivalent verbal IQ scores, although there may have been differences in the way the subjects actually used their verbal abilities during the task.)

Time Estimations. Verbal and nonverbal estimates of delay times did not show reliable differences between groups and it is unlikely that differences in choice were due to differences in the ability to estimate or count. The verbal and nonverbal time estimation data showed that all subjects were capable of discriminating between the two delays. Although the typical subjects were slightly more accurate at estimating the long delay, the estimate differences between the groups were not significant. In general, both groups were fairly inaccurate in their time verbal estimations, with the 16 s delay assigned any value from 1 minute to 3 hours. Two of the typical children who were seen counting during the task gave the number they had counted up to during the verbal questioning. Some children who were seen counting during the task did not count during the nonverbal estimations and some who did count during the task and during their subsequent nonverbal estimations, did not give verbal estimates that corresponded in any way to that count (e.g., a subject would count to 25 during the choice task but say he waited 3 minutes for 3 nickels). (The Pearson product-moment correlation revealed that there was no relationship between the two forms of verbal estimates given by the subjects.)

It is possible that significant differences between the groups would have emerged in older children who would be more verbally skilled, particularly during the verbal estimation procedure where most of these younger subjects performed poorly. The Cappella et al. (1977) study that found differences between hyperactive and normal subjects used older children whose ages ranged from 7 to 12 years. In the future, researchers who study self-control differences among older children should assess differences in verbal estimation abilities.

Verbalizations Made during the Choice Task

Differences in self-control may have been influenced by the type of verbalizations subjects made during the task (Anderson & Moreland, 1982; Hartig & Kanfer, 1973; Toner, 1981). It is impossible to know what type of covert statements subjects made, but ADHD children reported more frequently that they were talking to themselves or thinking about something during the delay times. Subjects said they were thinking about the toys, playing with cousins, getting out of the session, and so on. From these data it is not clear that subjects in either group used different types of verbalizations or that the verbalizations influenced choice.

Effect of the Provision of Alternative Activities in Phase B

In Phase B, music and toys were provided to determine whether the use of the additional activities would facilitate choice of the delayed reinforcers. The use of toys and music could easily be measured, while the use of other possible "mediating" responses, such as covert verbalizations were inaccessible to the experimenter. These intentionally programmed alternative activities did not alter self-control as they did in other studies. For instance self-control was seen to increase when the investigators presented music (Logue, King, Chavarro, Volpe, in press), symbolic distractors representative of the rewards (Mischel, Ebbensen, & Zeiss, 1972) or an alternative response key and reinforcement (Grosch & Neuringer, 1981).

There may be several reasons why the additional activities failed to increase self-control in this study. It is unlikely, but possible, that the music and toys would have differentially affected each group and increased typical children's self-control but not that of ADHD children. This effect were it present, may have been obscured by a ceiling effect among the typical boys, since they were already choosing the delayed reinforcers at such high rates. A more likely possibility is that this procedure was not well suited to testing the effect of the additional distractors. Informal observations, suggested that the trial length may have been too short, causing the use of the music and toys to be interrupted too frequently to test the hypothesis. Often, it seemed that subjects had just begun enjoying the toys when the siren sounded to signal the availability of a new trial, and subjects would have to stop playing with the toys and initiate the trial. Toy play also was interrupted when the subjects deposited the nickels in the bank. Some subjects seemed overwhelmed by all of the concurrent schedules available. The B phase might have been more effective if the trials had been longer and the additional stimuli not required the use of the boys' hands or interfered with the operation of the apparatus.

The ADHD subjects seemed particularly flustered by all of the activities and may have profited more from the programmed activities due to their method of engaging with them. Eventually most of the typical children learned to use one toy at a time, or operate the music with one hand and the apparatus with the other one. The ADHD children often held onto multiple toys simultaneously and consequently dropped the toys and nickels more frequently. Perhaps, they stopped using the additional activities earlier in the phase than the typical children. In addition, ADHD subjects seemed to use the spin toy in more destructive ways, such as banging it against the apparatus or holding it against the apple bank and attempting to "slice" the bank or the worm in it. Further analysis of the videotapes may show that there are other ways of scoring subject behavior that may highlight the differences between the groups and the ways they interacted with the additional activities.

The additional activities were more successful in lowering excessive rates of activity in the ADHD group (as measured by rates of nonfunctional responses on the apparatus and actometer movement). Subjects in both groups were out of their seat more frequently during the B phases, however. Many of the subjects danced to the music and pretended to use the music cord as a microphone while singing the song. Subjects left their seats at higher rates because it gave them easier access to the equipment and toys.

Overall, subjects seemed to be engaged more in task related activities during the B phases than the A phases. ADHD subjects were more on-task during the B phases in that they were physically closer to the apparatus and more likely involved in the programmed alternative activities (music and toys) in contrast with the A phases, when they were more involved with activities disapproved under most circumstances (e.g., spinning chairs, diving under tables). Previous research (Zentall & Meyer, 1987; Zentall & Zentall, 1976) has shown that hyperactive children are less active, make fewer impulsive errors, talk less and make fewer noises during conditions where increased stimulation is provided. Thus, although the additional activities did not facilitate choice for the delayed reinforcers, it may have helped the ADHD children disengage from less appropriate activities.

<u>Rates of Activity and the Development of Non-Programmed Alternative Responses</u>

Rates of activity clearly differentiated the groups, with the ADHD boys showing evidenced much higher rates of gross motor movements than the typical boys. As Zentall and Zentall (1976) found, rates of activity were higher on the second day than on the first. In general, the time of the ADHD subjects' near the apparatus decreased. This decrease was reflected in the lower rates of nonfunctional responses on the apparatus, slightly longer initial link latency response times, and the significant positive correlation between actometer scores and initial link response times.

In general, these data suggest that the reinforcing strength of the nickels and choice task decreased over time for the ADHD subjects. The observations indicated that the ADHD children increasingly were engaged in activities other than the choice task as the phases progressed. The typical children rarely left their seats, except to put the nickels in the bank. When the typical children fidgeted, it was usually with objects that were within an arm's reach of their chair. Many of the typical subjects also caught the nickels as they were dispensed from the machine. By contrast, the ADHD subjects involved themselves in a number of non-task related activities including trying to undo the bank's clamp, tinkering with the telephone, opening desk drawers, jumping on top and under chairs and a table, and maneuvering a chair on wheels in a variety of original ways, especially by the end of the second day. During the first day many of these subjects moved the chair 1-2 feet away from the apparatus, while they watched for observers. They waited a minute or two before moving the chair again (as if they were waiting for a reprimand) and then proceeded to wheel across the room. By the second day they were frequently several feet from the apparatus. The experimenter entered the room if a subject sat on top of the chair's back to prevent any subject from falling and injuring himself. She did not reprimand them for playing with the chair (invariably subjects heard her turn the handle to open the door and would sit down before she entered the room). By the middle or end of Day 2 some of the ADHD subjects seemed irritated that they had to abandon their "games" to respond to the apparatus. On the second day some of the ADHD subjects left the testing room and a few knocked on the observation room door. When the experimenter asked what they wanted their responses varied from saying nothing, to saying that they wanted to see where the experimenter was, to saying that they wanted to leave (1 subject). Subjects were ushered back into the testing room and told that the experimenter would return shortly to count the nickels. The subject who asked to leave (a boy who exhibited extremely high rates of nontask related activity and noncompliance) was reminded that he would not be able to earn a toy if he left. During the last phase of the second day he opted to leave rather than finish the session.

Conceptual Accounts for Group Differences in Self-Control

Several reasons may explain the decreased rates of choosing the delayed reinforcers and the increased rates of activity in the ADHD group. These explanations are not mutually exclusive of each other. Some of the models and descriptions are dependent upon other descriptions, but serve to highlight specific aspects of the data in greater detail.

The Immediate Reinforcer Would Terminate the Experiment Earlier

The first possibility is that ADHD subjects developed and followed an inaccurate rule that said they could leave the experiment earlier if they chose the immediate reinforcer. (This rule was incorrect because the postreinforcer dark times served to equate trial and overall session length irrespective of choice.) The testing situation may have become so aversive, or activities outside of the testing situation so attractive, that escape from the experiment became an effective reinforcer. Responding during the phase many only have been maintained by overriding instructional control,such as parents telling the child to participate, and/or the opportunity they had to exchange nickels for toys at the end of the phase. Although this explanation may have some merit, it fails sufficiently to explain why the ADHD children would have preferred to leave earlier than the typical children did and why their rates of activity were so much higher.

<u>Reinforcer Deprivation and Molar Equilibrium Theories</u>

Another possibility is that the ADHD subjects were deprived of reinforcers with which they normally had contact. Deprivation is an operation in which there is a "reduction in the availability of a reinforcer, that increases the reinforcer's effectiveness" (p. 332, Catania, 1968). In this interpretation, "deprivation works to make reinforcers effective because it restricts the organism's opportunity to engage in some response, and by so doing makes that response more probable" (p.67, Catania, 1984). In this view the effectiveness of a reinforcer is determined by the availability of other reinforcers. (See Premack, 1962 for more on how reinforcing effects of stimuli vary depending on the probability of the occurrence of a response). The molar equilibrium theory (Timberlake, 1980) offers an even more inclusive and contextual way of conceptualizing the subjects' response allocation in the present study and states,

> . . . there exists a stable set of conditions that an organism will approach or maintain under circumstances that perturb or challenge these conditions. . . . If a schedule perturbs the equilibrium condition by forcing responding away from its baseline expression, the organism is presumed to act to reduce the resultant disequilibrium. (p. 9)

In this hypothesis an organism will distribute its responding among alternative reinforcers to gain an optimal amount of reinforcement. In this study, engagement with the choice task would have restricted the children from other responses, for example gross motor activities, which as time passed enhanced the reinforcing value of the motor activities. The reinforcing effectiveness of the nickels and the choice task, then needs to be assessed relative to the other activities available.

The reinforcing effectiveness of doing other activities outside of the choice task may have increased as children were following instructions and participating in the choice task. By the end of the first day and the second day, the ADHD subjects may have become so deprived of particular activities outside of the choice procedure, that the nickels lost much of their reinforcing effectiveness relative to the effectiveness of other available activities. Choosing the immediate reinforcer may have permitted these subjects to resume their engagement with the nonchoice activities in the room more quickly. Choosing one nickel also was quicker in that it required less time to deposit it than would three. Ultimately, the subjects may have become deprived of reinforcers that were outside of the testing situation, and tried to distribute their responding to obtain the optimal level of reinforcement available within the session. Although this explanation may have some merit, it does not easily explain why the boys chose the larger reinforcer less frequently during the first phase of the second day than they had previously. Given the interim of a week or two between the first and second day, the subjects should not have been experiencing deprivation so easily during the first phase of Day 2. Deprivation effects would more likely be seen later on in the testing, unless the nickels lost some of their reinforcing effectiveness and this loss was maintained over 2 weeks and in order to maintain an "equilibrium" state subjects sought out reinforcement from elsewhere (e.g., motor activities).

Instructional Control
and Rates of Reinforcer Sampling

Differences in responding between the groups also may have been due to higher rates of sampling nonprogrammed alternative activities due to the generally higher rates of activity and lower rates of compliance that ADHD subjects exhibit. By being more active, they naturally may test other activities for their potentially reinforcing effectiveness. Children who were compliant and remained in their seats during the choice task would have been less likely to discover the reinforcing effects of spinning a chair around, turning the lights out to watch the sparks on a spin toy, or operating the handles on the apparatus with their feet. They would certainly be less likely to generate the complex behavioral chains that some of the ADHD children did around the room's furniture. The ADHD subjects may have been particularly "susceptible" to engaging in these other activities once they learned those responses would be reinforced immediately. The reinforcement for spinning a chair was delivered immediately, while they had to wait 16 s for 3 nickels; this learning may have altered choice responding.

Noncompliance to rules by the ADHD children may have accounted for differences between the groups in other ways. Following a rule, in and of itself, is a form of self-control, rules typically are given when the outcome is delayed, has a low or moderate probability of occurring, or the outcome is less effective in comparison to available alternative reinforcers (Malott, 1989). Sonuga-Barke et al. (1989b) have suggested that younger children choose larger rewards because they are deemed more socially acceptable. If choosing larger rewards is a function of delayed social consequences (and rules), then children whose behavior is under weaker instructional control would be expected to choose the delayed, larger rewards less frequently.

Habituation or Adaptation

Another possible explanation for the decrement in the ADHD subjects' choice of the delayed reinforcers may be due to habituation or adaptation. Habituation is a "decrement in an unlearned response as a function of repeated presentations of the stimulus controlling the response" (p. 49, Donahoe, 1980). Adaptation is a similar process and is defined as "a diminution produced by continued or repeated exposure(s), in the respondent behavior elicited by a particular stimulus or stimulus complex (e.g., the experimental chamber)" (p. 327, Catania, 1968), however, the term also has been used to describe diminutions in rates of operant behavior (Sulzer-Azaroff & Mayer, in press). Therefore, the two terms will be used interchangeably. (Since data from this study are from an operant procedure, an interpretation based on habituation is merely an extrapolation). There are two possible explanations based on the concept of habituation for the choice and activity data; first that habituation occurs more slowly in ADHD children, or alternatively that habituation happens faster in ADHD children than typical children.

There is some evidence of slower "voluntary" habituation in children diagnosed as hyperkinetics in comparison to children diagnosed as neurotic (Conners & Greenfeld, 1966 as cited in Conners & Wells, 1986). Habituation is frequently tested by repeatedly presenting a sudden, loud stimulus, such as a noise emanating from a starter's pistol. Investigators measure the change in magnitude of a response over the repeated presentations of the loud stimulus. Conners and Greenfeld (1966) fired a starter's pistol 12 times and told subjects to press a button that was underneath their right hand, while leaving the left hand absolutely still. Responding on the right hand was considered voluntary and the left hand involuntary. The amplitude of responding was compared between groups and hands. The groups did not differ in their mean amplitude of responding on the the voluntary hand, but the hyperkinetic group did show significantly slower response decrements with the instructed voluntary hand. If ADHD children habituate more slowly to stimuli, they may have low arousal thresholds and be more easily affected by extraneous stimuli in the environment than typical children. In the low arousal interpretation the alternative stimuli in a setting will be more effective in controlling responding and may serve to decrease on-task behavior. This model may explain why ADHD children are more active, sample other stimuli more frequently, and are more responsive to immediate reinforcement.

Current evidence though is insufficient to confirm that ADHD children respond with slower habituation decrements or that they have a low arousal threshold. There has been controversy for several years in the hyperactivity literature concerning various theories of under- and overarousal, and a general inability to modulate arousal. The interested reader may wish to read other literature that discusses these theories in more detail (e.g., Haenlein & Caul, 1987; Ross & Ross, 1982).

With the preceding cautionary note, more rapid habituation in ADHD children may be another explanation for the patterns of choice and activity data found in this study. This author knows of no current direct evidence linking faster habituation to the ADHD population, but it is a hypothesis worth considering, since only one study shows contradictory results and faster habituation is more closely related to other existing models of ADHD responding. If ADHD children habituate faster to one stimulus you would expect to see other stimuli controlling their responding at higher rates. From this perspective, the ADHD population has a high arousal threshold and requires more effective reinforcers to maintain responding to a particular stimulus. Again, delay to reinforcement as well as magnitude may alter the effectiveness of a stimulus and in ADHD children delay to a reinforcer may be more influential than magnitude. Thus, a particular stimulus that is immediate may have more of a reinforcing effect than a delayed, larger reinforcer. However, the immediate reinforcer may not be enough to maintain responding and other available reinforcers would need to be accessed. Choosing the more immediate reinforcer would permit one more quickly to access other immediate reinforcers, since less time would need to be devoted to depositing the nickels in the bank.

Reward Threshold

Haenlein and Caul (1987) have hypothesized that the reward threshold of hyperactive children is higher, requiring larger magnitudes of reinforcement to maintain ADHD children's responding. The authors review pharmacological and behavioral research to support their model (Firestone & Douglas, 1975) showing that hyperactive children exhibit slower and more variable reaction times and more errors under FR 2 schedules but performances equivalent to that of normal subjects under continuous reinforcement schedules. The Haenlein and Caul model may fit the data from this study in that responding of the ADHD subjects seemed to require more stimuli than typical subjects, since they were engaged in a greater variety of apparently more reinforcing activities. However, their model would not explain the decrement in rates of choosing the larger reinforcer. Instead, the model would predict that ADHD subjects would choose the larger reinforcer while also engaging in alternative reinforcing activities during the delay periods; in this way subjects would earn the greatest magnitude of reinforcement. Some of the ADHD subjects did seem to learn this strategy by the A_2 phase of Day 2 when they increased their choice for the larger reinforcer while engaging in a number of motor activities as well.

Satiation

The process of satiation may more parsimoniously describe the data in this study. Satiation also is a more appropriate concept to invoke in interpreting the data in the present study, since satiation refers to an operant, rather than respondent relationship (e.g., habituation). Catania (1968) defines satiation as "a drive operation, the continued presentation or availability of a reinforcer, that reduces the reinforcer's effectiveness ..." (p. 345). Barkley (in press) has suggested that the responding of hyperactive children satiates more quickly than responding in typical children. He points out that certain stimuli are initially effective in increasing or sustaining responding, but that the reinforcer effectiveness of these stimuli decline more rapidly with hyperactive children. A satiation hypothesis could therefore explain the decrement in choosing the larger reinforcer and the increased rates of responding to other stimuli. With satiation to the nickels, one would expect to see choice of the immediate reinforcer increase, time engaged with the nickels (e.g., looking, holding, or inserting them into the bank) lessen, and perhaps time engaged in other responses correlated with the nickels and the apparatus that may have produced conditioned reinforcers also lessen. From informal observations the ADHD children did spend decreasing periods of time around the apparatus on Day 2 (this also can be inferred from the higher scores on the actometers and lower rate of nonfunctional responses on the manipulanda). However, the videotapes would need to be examined further to demonstrate whether the rates of handling the nickels differed between groups and days and correlated with choice for the larger reinforcer. With satiation to one stimulus (e.g., nickels) there should be an increase in behavior that leading to alternative forms of reinforcement (e.g., chair spinning). Although differences between the groups did not emerge in rates of responding on the programmed activities (e.g., spin toys and music) the ADHD group was involved in much higher rates of responding for stimuli unrelated to the choice task, particularly as exposure to the task increased.

If the ADHD subjects had satiated to the nickels why did they even complete the task? One would hypothesize that they would ordinarily stop responding all together and ask to leave the experiment. Responding was probably maintained by parent and experimental implicit instructional control and the opportunity to earn a toy at the end of the phase. Perhaps the strongest reinforcer, though, was the opportunity to end the session. Most subjects followed an implicit rule that said they had to continue responding until the experimenter said the phase was over in order to buys the toys at the end of the phase.

Differences in the children's verbal reports also may reflect satiation differences. Parents of boys from both groups reported that their children were excited about coming back on the second day and that they had talked to friends and classmates about the "nickel game". By the end of the second day, some of the typical subjects asked the experimenter and their parents if they could return for a third day. Some were clearly disappointed to learn that the second day was the final day. None of the ADHD subjects expressed an interest in returning on a third day, and many expressed boredom with the experiment by that time, including those who appeared to start the day excitedly.

Several interpretations, descriptions, and extrapolations from the data in this project have been presented. Unfortunately none can be supported unambiguously, given the present data set. Certain interpretations, do match the data better though (the concomitant decrease in choice for the larger reinforcer and increase in rates of activity). Perhaps the processes responsible for producing the results interact with one another and/or may be dependent on one another. For example, weak instructional control by implicit rules interacts with many of the previously discussed hypotheses. At this point, it would be most prudent to describe the data rather than rely on theoretical models.

Implications Derived from the Choice Task

Measurement and Diagnosis of ADHD

A standardized, computerized task requiring clients to choose between immediate, small reinforcers and delayed, larger reinforcers may prove to be a useful diagnostic tool in the future. Objective methods of measuring deficits associated with ADHD are needed and the procedure used in this study contains some essential components lacking in other diagnostic tools. Additionally, this choice task can be modified to match individual reinforcement histories and also can be adjusted for use with younger children (e.g., Schweitzer & Sulzer-Azaroff, 1989), although more testing must be done to determine if it is equally amenable for use with older children as well. Procedures that use nondiscrete trial, more traditional concurrent schedule procedures (e.g., Sonuga-Barke, 1989b; Logue et al., in press) also may reveal differences between self-control responding in clinical groups. These procedures need to be correlated with current ADHD measurement techniques to determine the possible validity of such choice procedures as diagnostic tools.

Treatment

This study verified some common conceptions about self-control responding in a sample of ADHD children. Typically people who have frequent contact with ADHD children discriminate that these children get "bored" more quickly than their peers and that it is important to alter stimuli used as reinforcers more frequently before those stimuli lose their effectiveness. This study also showed that it may be helpful to allow additional access to some stimuli during tasks to prevent ADHD children from engaging in fewer nontask related activities. It is important to try to provide the novel reinforcers and alternative forms of reinforcement before the children find other less appropriate ones. As one parent of an ADHD subject told the experimenter, she would never think to take her child on a long car ride or a doctor's visit without a supply of games and rewards to keep him busy. This study did not show that the use of alternative rewards would increase self-control but perhaps the procedure did not permit an appropriate test of the hypothesis.

Suggestions for Future Research

Procedural Questions

A number of variations on the procedure used in this study should be tested in the future. This task may not have optimally measured the effects of the prereinforcer delay and it is possible that the procedure could be altered to increase its sensitivity to detecting self-control differences. Postreinforcer delays also may have affected responding, particularly that of the ADHD group. The original procedure used a 30 s predelay and a fixed interval postdelay (rather than variable) because some subjects expressed their irritation at having chosen the immediate reinforcer and then having to wait a long time before they could start the next trial. In a sense, choosing the immediate reinforcer was not only less effective because of the lower magnitude of the reinforcer, but also because it resulted in a much longer time to begin the next trial. One pilot subject told the experimenter that he was going to choose the delayed reinforcer because he had to wait so long until the next trial started after he chose the immediate schedule. Future studies should be directed toward testing the effects of postreinforcer delays on responding. Although Logue, Smith, and Rachlin (1985) found no effect of the postreinforcer delays on pigeons' responding, postreinforcer effects may be greater with verbal humans who may be more capable of distinguishing between time delays.

Future research also should examine the effect of longer prereinforcer trials with access to alternative forms of stimuli. Longer trials may produce responding that is more effectively reinforced by particular forms of stimuli. For example, subjects could be given 5 minute trials and listen to short stories or draw a picture. Perhaps subjects would be less "overwhelmed" with such a task.

Investigators also should compare the effect of food and nonfood reinforcers on responding. Typically pigeon research on choice has involved food. Food is a very strong reinforcer for all organisms and studies that have used food have also shown high rates of impulsivity (e.g., pigeons, Mazur & Logue, 1978; mentally retarded adults, Ragotzy, Blakely, & Poling, 1988; preschool age children, Schweitzer & Sulzer-Azaroff, 1989). We may learn more about self-control differences by comparing the effect of differing stimuli that have varying levels of effectiveness as reinforcers.

Therapeutic Analogs

In an earlier study (Schweitzer & Sulzer-Azaroff, 1989) investigators implemented a similar procedure to increase the selection of larger, more delayed reinforcers in preschool-age children. The training procedure consisted of gradually increasing the durations of the delay interval for the larger reinforcer over sessions. This procedure, however, was not computerized and subjects selected rewards before each trial and received their primary rewards (e.g., food or stickers) after each trial. It would be interesting for researchers to use the same shaping procedure with the computerized program used in the present study. This may teach us more about how behavior is modified as self-control increases.

Developmental and Applied Research

This study has pointed to a number of topics that may have direct implications for understanding the development of self-control and the possible amelioration of associated deficits. Sonuga-Barke et al. (1989a, 1989b) have begun to study the developmental aspects of self-control with a concurrent chain schedule, but a number of other developmental questions remain about this area of research. Using a variety of choice procedures, developmental differences should be examined to determine why younger children and perhaps ADHD children, show less choice for larger, delayed reinforcers in these procedures than adults.

Certainly, we need to learn more about the nature of the differences between the ADHD and typical groups, including what we can do to improve self-control in the ADHD children outside of, or in conjunction with medication. Future studies should try to examine more closely the differences in the "mediating" responses between groups when children are trying to delay and the strength of conditioned reinforcers that may alter choice for delayed reinforcers.

Researchers also need to learn more about self-control differences in more naturalistic situations. Perhaps the effectiveness of particular reinforcing activities in a playroom could be measured against other activities and experimenters could measure choice for the different activities.

To learn more about the effects of stimulants on ADHD children testing the effects of pharmacological agents on responding during the choice task would be useful. Were the task sensitive to pharmacological treatment, the choice procedure would prove to be even more promising as a diagnostic tool. The procedure also should be measured against other measures used to diagnose ADHD, such as the Gordon Diagnostic System vigilance task, the Matching Familiar Figures Test, and the Self-Control Rating Scale.

Lastly, a more molecular analysis of the children's responding during the choice task must be performed. A closer examination may reveal differences in what members of the two groups were doing during the delay times that influenced choice. The type of verbal or motor responses made during those times may have differed. Furthermore, the the use of the toys and music may have differentially affected the groups with one group alternating more frequently between the additional stimuli. Only a closer analysis would reveal the veracity of those differences.

Conclusion

In this experiment, subjects chose between larger more delayed reinforcers and smaller more immediate reinforcers, with choice of the larger reinforcer considered an aspect of self-control. The purpose was to determine if the procedure would discriminate between typical and clinically diagnosed ADHD children and whether access to additional reinforcers would increase self-control. The results demonstrated that the ADHD children chose the more immediate smaller reinforcers more frequently over time than the typical children did. Adding alternative programmed reinforcers did not increase the ADHD children's self-control, but they apparently discovered other reinforcers in the environment. These findings have implications for understanding the self-control differences between ADHD and typical children and suggest ways to measure those differences. The specific causal variables that would have accounted for the differences between the groups remain to be determined.

APPENDIX A

DSM-III-R DIAGNOSTIC CRITERIA FOR ADHD

DSM-III-R DIAGNOSTIC CRITERIA FOR ADHD

The following is the diagnostic criteria for Attention-deficit Hyperactivity Disorder, according to the most recent revision of the Diagnostic and Statistical Manual of Mental Disorders [DSM-III-R (APA, 1987, p. 52, 53)]

Note: Consider a criterion met only if the behavior if considerably more frequent than that of most people of the same mental age.

A. A disturbance of at least six months during which at least eight of the following are present:

(1) often fidgets with hands or feet or squirms in seat (in adolescents, may be limited to subjective feelings of restlessness
(2) has difficulty remaining seated when required to do so
(3) is easily distracted by extraneous stimuli
(4) has difficulty awaiting turn in games or group situations
(5) often blurts out answers to questions before they have been completed
(6) has difficulty following through on instructions from others (not due to oppositional behavior or failure of comprehension), e.g., fails to finish chores
(7) has difficulty sustaining attention in tasks or play activities
(8) often shifts from one uncompleted activity to another
(9) has difficulty playing quietly
(10) often talks excessively
(11) often interrupts or intrudes on others, e.g., butts into other children's games
(12) often does not seem to listen to what is being said to him or her
(13) often loses things necessary for tasks or activities at school or at home (e.g., toys, pencils, books, assignments)
(14) often engages in physically dangerous activities without considering possible consequences (not for the purpose of thrill-seeking), e.g., runs into street without looking

Note: the above items are listed in descending order of discriminating power based on data from a national field trial of the

DSM-III-R criteria for Disruptive Behavior Disorders.

B. Onset before the age of seven.

C. Does not meet the criteria for a Pervasive Developmental Disorder.

Criteria for severity of Attention-deficit Hyperactivity Disorder:

Mild: Few, if any, symptoms in excess of those required to make the diagnosis and only minimal or no impairment in school and social functioning.

Moderate: Symptoms of functional impairment intermediate between "mild" and "severe".

Severe: Many symptoms in excess of those required to make the diagnosis and significant and pervasive impairment in functioning at home and school and with peers.

APPENDIX B

DEFINITIONS FOR CODING BEHAVIOR CATEGORIES

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Fidgeting. Any repetitive, purposeless motion of the legs, arms, buttocks, or trunk. It must occur at least twice in succession to be considered repetitive and it should serve no purpose. Examples: swaying back and forth, kicking one's legs back and forth, swinging arms at one's side, shuffling feet from side to side, shirfting one's buttocks about in the chair, spinning the chair in or out of it, touching apparatus in a repetitive motion, pounding on the desk, fiddling repeatedly with the actometer or other objects. Do not score as fidgeting if child is playing with the bank.

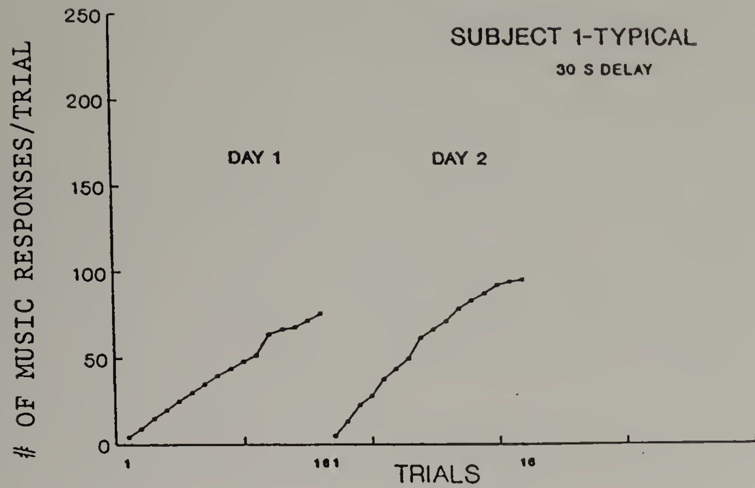
Out of Seat. Any time the child's buttocks break the flat surface of the seat in which he is sitting. This includes going to another chair in the room and sitting in it.

[Adapted from the Restricted Academic Situations Task (Barkley, 1988)]

APPENDIX C

CUMULATIVE GRAPHS ON THE NUMBER OF RESPONSES MADE TO LISTEN TO MUSIC

CUMULATIVE GRAPHS ON THE NUMBER OF
RESPONSES MADE TO LISTEN TO MUSIC



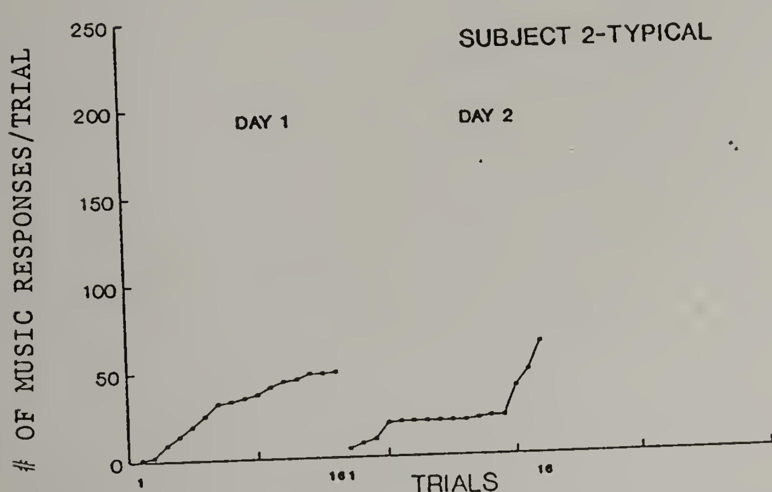
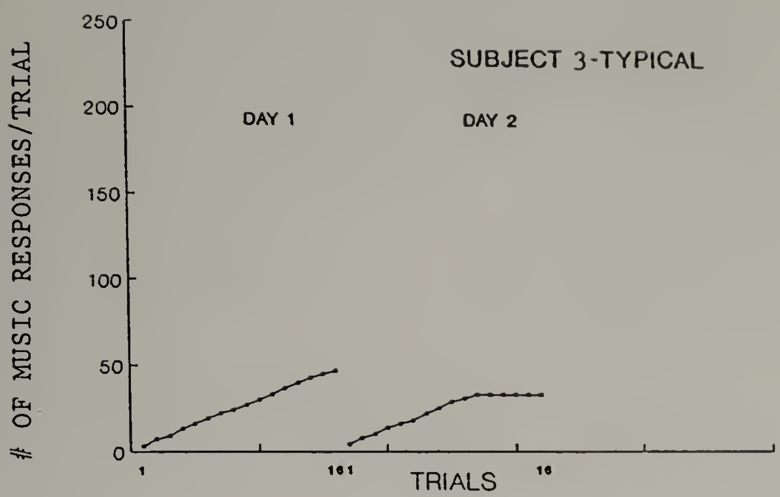


Fig. 7. Cumulative graphs on the number of responses per trial to gain access to 10 s of music. Continued, next page.



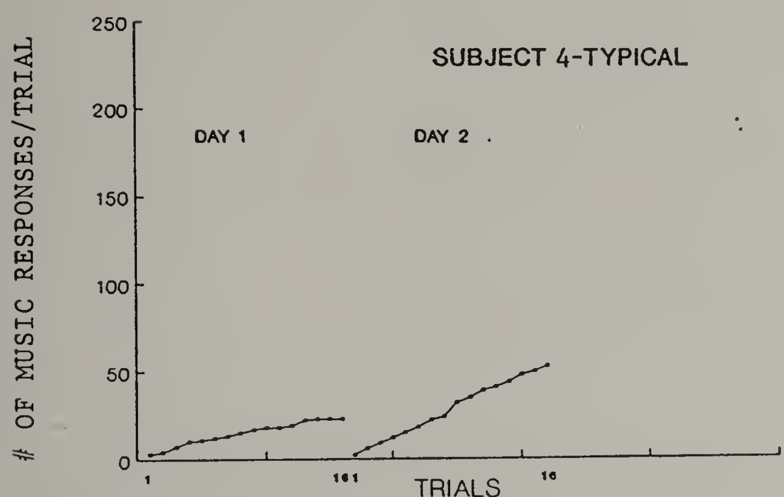
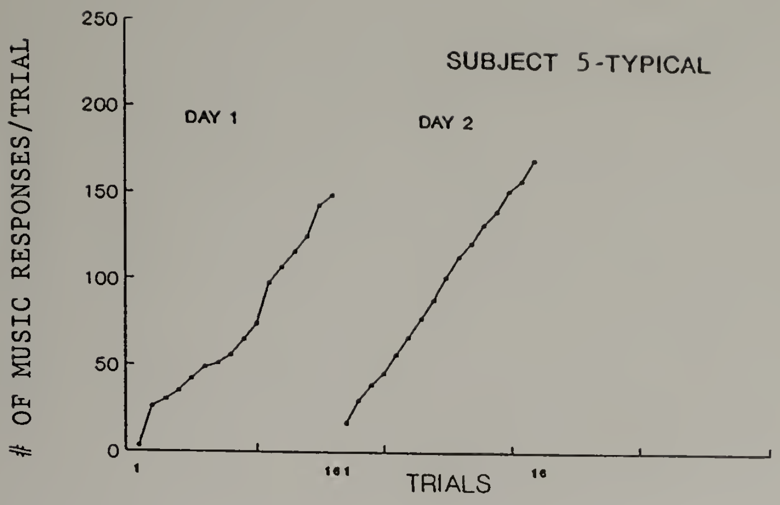


Fig. 7. Continued



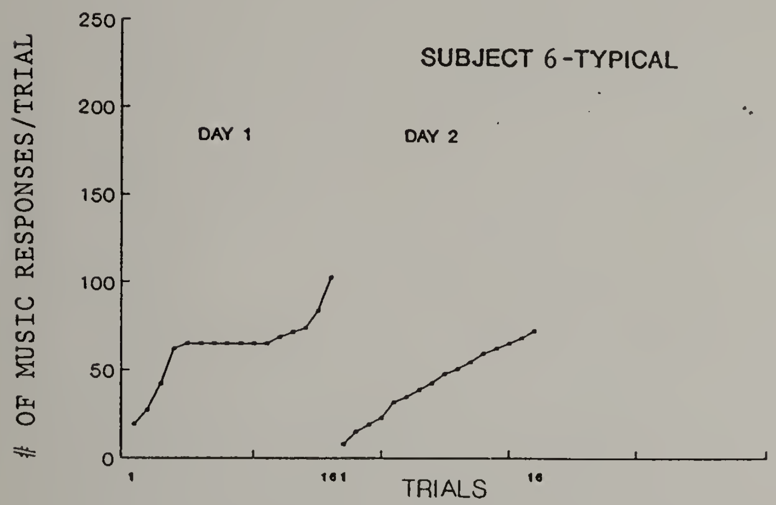
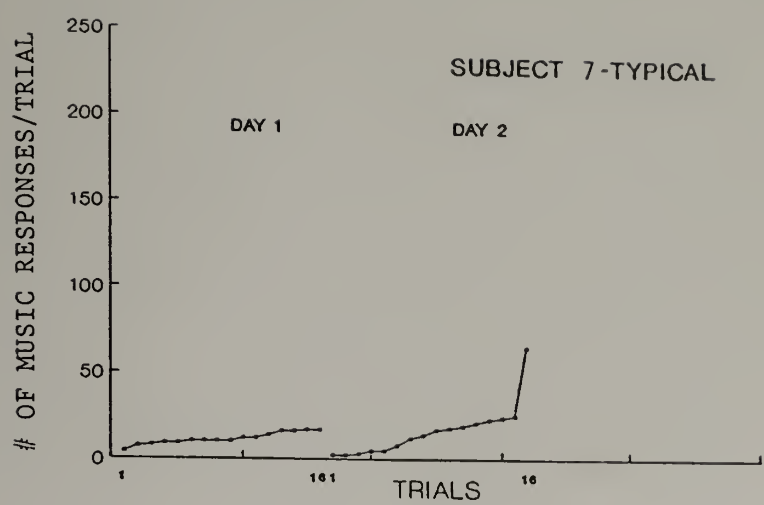


Fig. 7. Continued



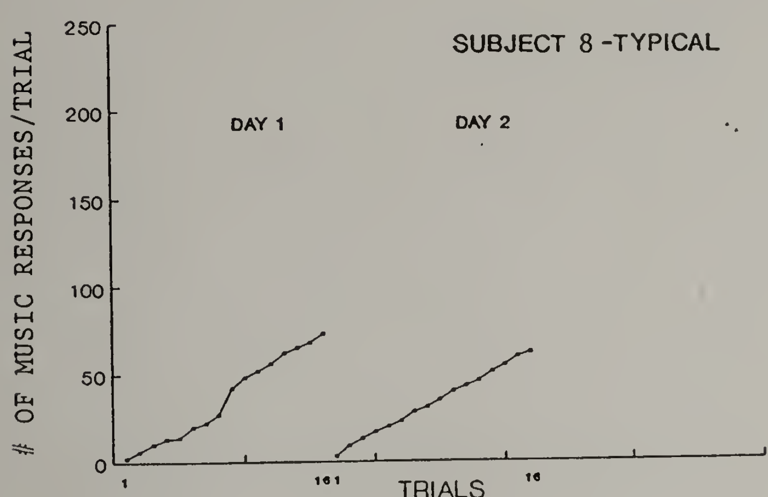
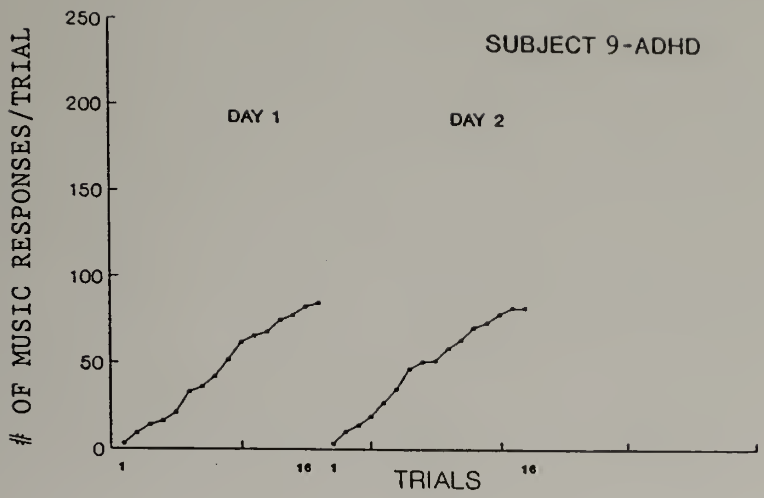


Fig. 7. Continued



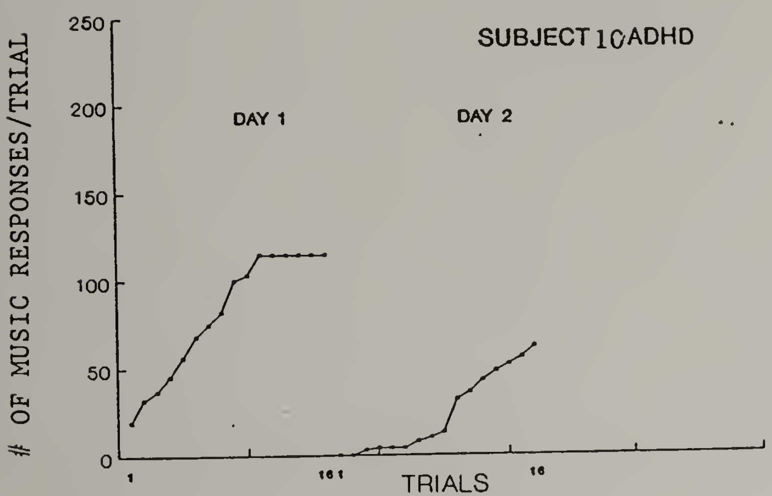
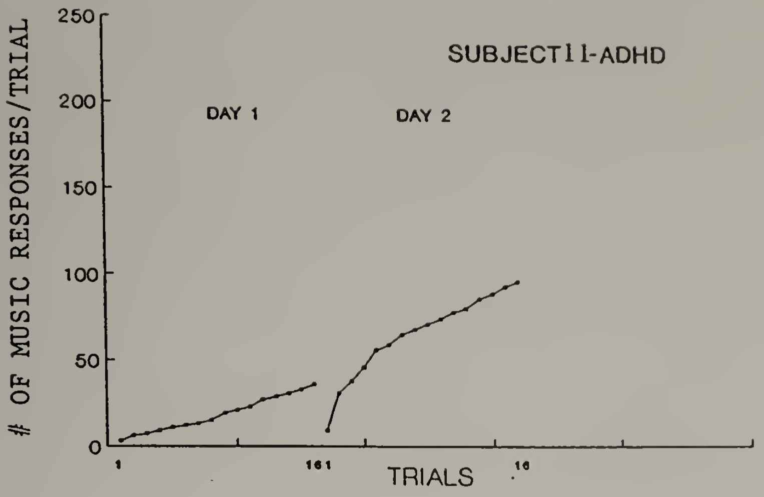


Fig. 7. Continued



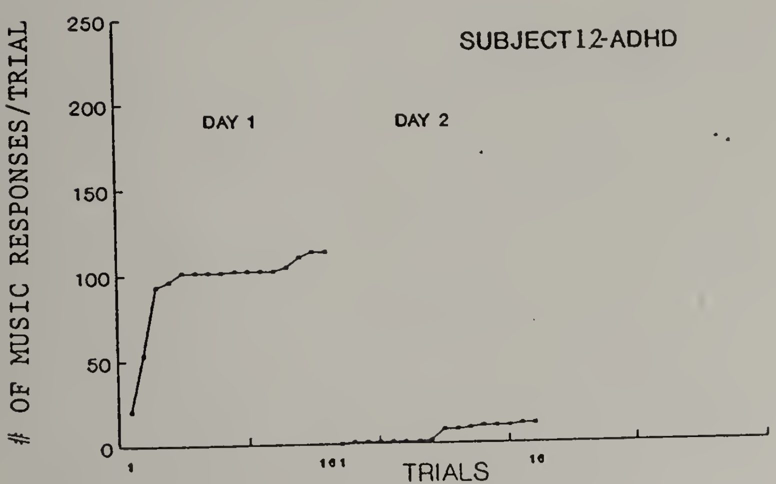
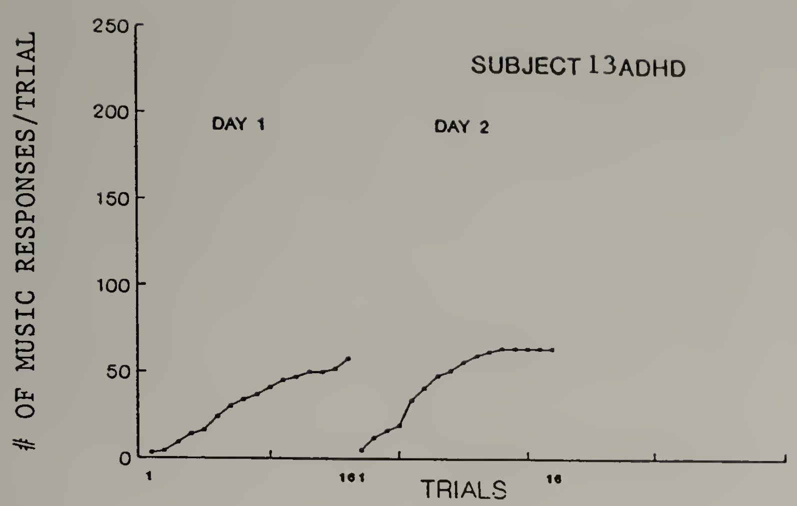
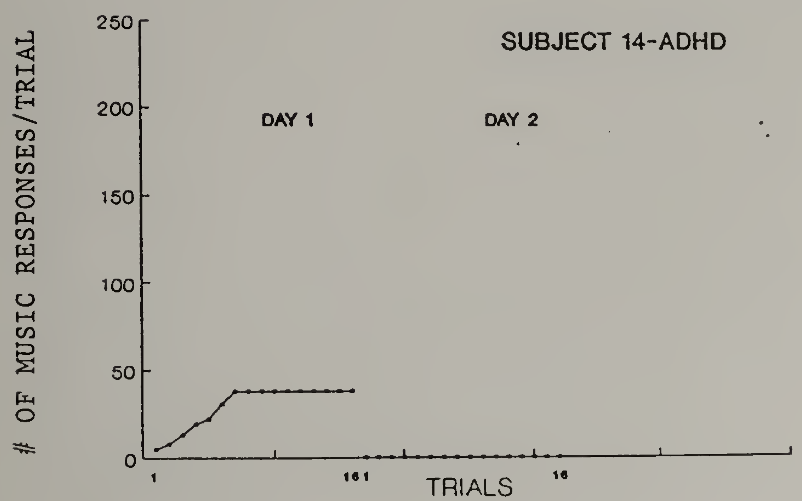


Fig. 7. Continued





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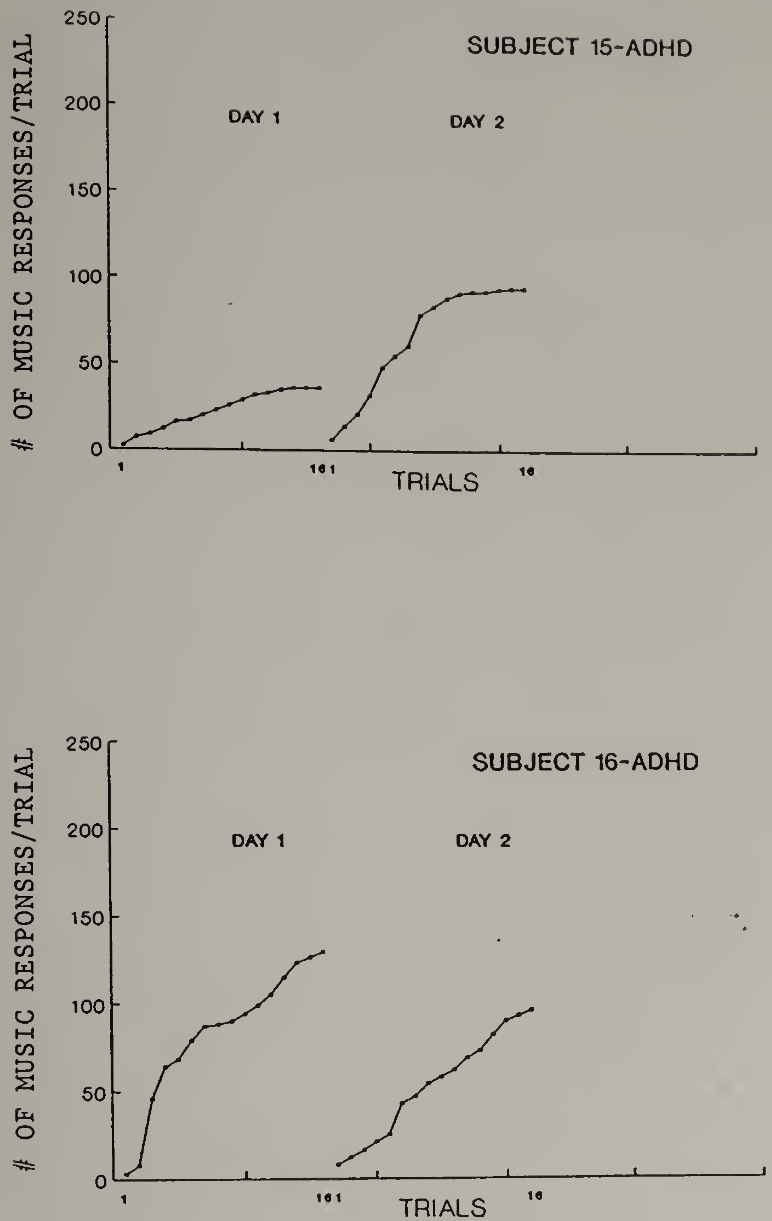
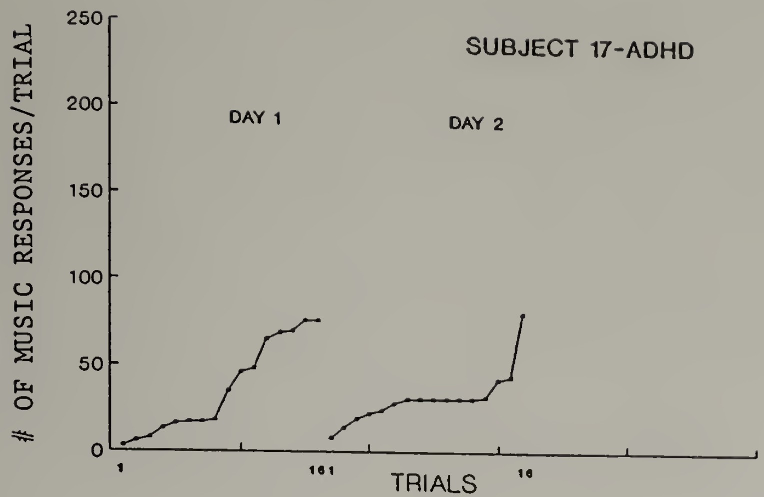


Fig. 7. Continued



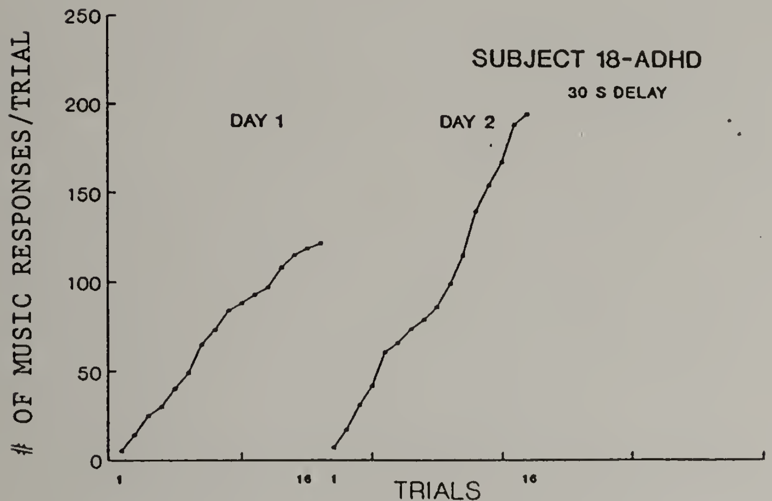


Fig. 7. Continued.

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